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Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY

SEPTEMBER 1958

COMPLETE TEXT OF NASA ACT

WHAT DO YOU KNOW ABOUT SPACE?

Optimum Paths to the Moon . . . A. E. Bryson and G. A. Ouellette

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Cold Propellants for Hot Performance . . . . . John L. Sloop

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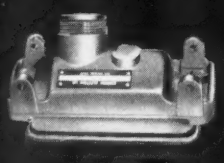

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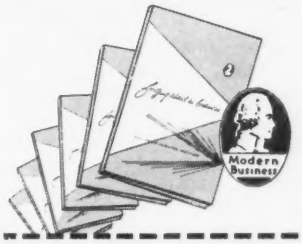

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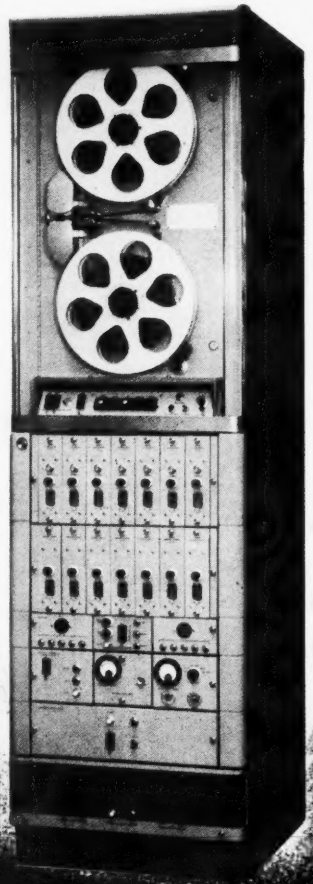

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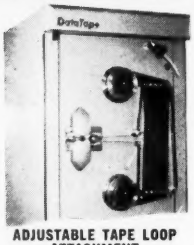

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DIGITAL MAGNETIC-TAPE RECORDER/ REPRODUCER

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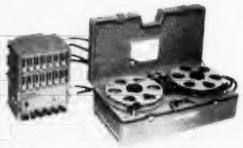

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The military and industry alike use the 5-752 in recording telemetered missile data, wind-tunnel testing, jet and rocket engine testing, shock and vibration studies, mobile and stationary structural testing, static and dynamic testing, sound measurements, and medical research.

Two exclusive design advances distinguish the 5-752 as a leader in the field of data recording and reproducing:

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The all-metal-surface of CEC's magnetic heads promotes a self-cleaning action and minimizes head wear. Oxide can't build up on heads to cause drop-outs or loss of high-frequency response.

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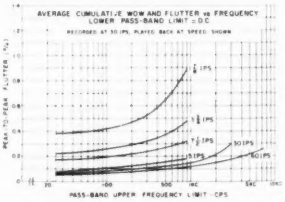
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PEAK-TO-PEAK FLUTTER, %
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15 IPS
7½ IPS
3¾ IPS
1⅞ IPS
PASS-BAND UPPER FREQUENCY LIMIT - CPS

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Astronautics

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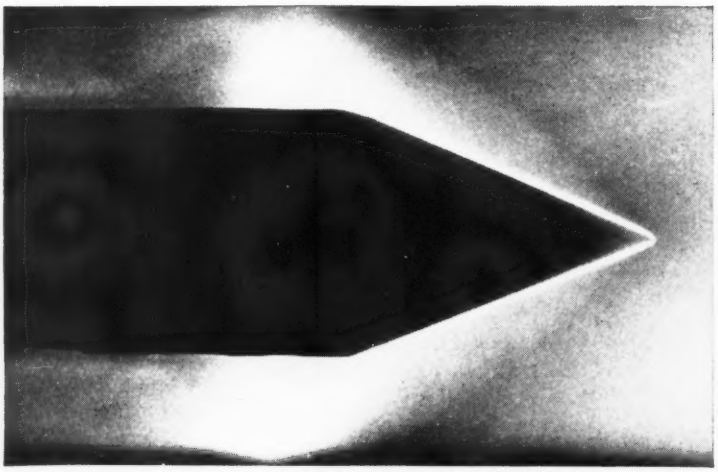
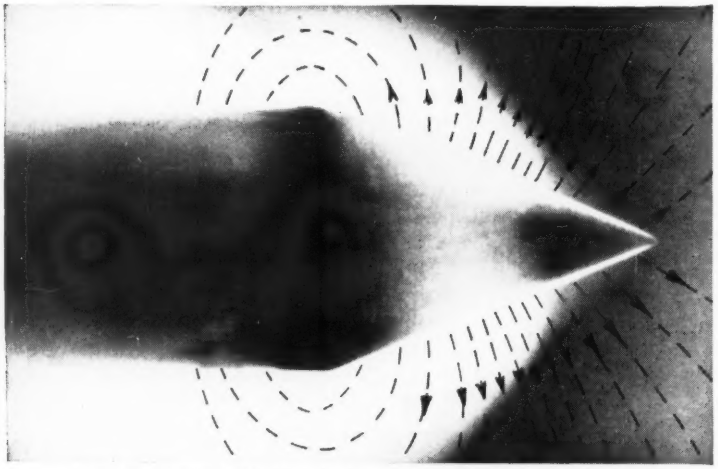
PROGRESS REPORT FROM AVCO RESEARCH LABORATORY

NEW LIGHT ON MHD*



NO MAGNETIC FIELD. This shock tube photograph, taken by emitted light only, shows the typical shock wave configuration formed by high-velocity gas flowing around a pointed cone.



WITH MAGNETIC FIELD. Here is shown the magnetohydrodynamic displacement of the shock wave. The magnetic field is caused by electric current flowing through a coil of wire within the cone. This experiment qualitatively demonstrates the interaction of a high-temperature gas with a magnetic field. This effect would be expected to produce drag and reduce heat transfer to the body.

The Avco Research Laboratory was founded a little more than three years ago for the purpose of examining high-temperature gas problems associated with ICBM re-entry. The success of this research led to the birth of a new corporate enterprise, Avco's Research and Advanced Development Division.

The Research Laboratory, now established as a separate Avco division, has expanded to embrace all aspects of physical gas dynamics. We are currently gravid with several embryonic projects which we anticipate will likewise grow into new corporate enterprises. Our work in the physics, aerodynamics and chemistry of high-temperature gases is growing in the following areas:

Magnetohydrodynamics—
Flight and industrial power-generation applications

Space flight—
Manned satellites
Electromagnetic propulsion

These developments have created a number of openings for physicists, aerodynamicists and physical chemists. If your background qualifies you to work in any of these areas, we would be pleased to hear from you.

Arthur Kantrowitz

Dr. Arthur Kantrowitz, Director
Avco Research Laboratory

P. S. A listing of laboratory research reports indicative of the scope and depth of our activities is available. Address your request: *Attention: Librarian, Avco Research Laboratory, 2385 Revere Beach Parkway, Everett, Massachusetts.*

***Magnetohydrodynamics,** the study of the dynamics of electrically conducting fluids interacting with magnetic fields.

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Astro notes

SPACE EXPERIMENTS

• Failure of Thor first stage midway through burning in the Aug. 17th moon shot was a blow to AF, which will have to identify source of malfunction before another Thor-Able launching. If the malfunction appears not caused by random errors in inspection, etc., Army's Jupiter, which reportedly has higher percentage of successful flight tests than Thor, and its Juno moon probe based on Jupiter both will get a big boost—Juno towards the moon and another possible Army "first." Thor-Able carried magnetometer, temperature and meteoroid detectors, and photocell scanner for sending image of moon's far side. Army probe would probably carry these and radiation-detection instruments.

• Explorer IV reported cosmic radiation dosage of 100 roentgens per hour at a point 1200 miles over South America—a lethal amount for man in a few hours. The radiation, apparently high-energy charged particles as yet unidentified, begins about 250 miles above the earth and extends to a point beyond the reach of any satellites launched to date.

• Balloon experiments are moving into high gear. In the wake of its successful unmanned balloon flight to 80,000 ft in July, which produced the first stratosphere TV pictures, the Navy announced it would send an astronomer and a telescope aloft in November to view Mars. Meanwhile, the Air Force, tuning up for its Manhigh III flight, in which Capt. Grover Schock was slated to remain aloft for an extended period of time at altitudes of 100,000 ft or more, lost the largest balloon ever launched (5 million cu ft) when it ripped open at 65,000 ft, less than halfway to its announced goal of 25 miles. It carried a monkey and other living organisms and was designed to study cosmic radiation effects.

MISSILES

• First models of Nike-Zeus were reliably reported to have been test-fired at the Pacific Missile Test Range in July under AEC supervision. Several missiles have reportedly been built, and there are strong rumors, as yet unconfirmed, that Nike-Zeus is to become an integral part of the BMEWS system.

• The Air Force, in the wake of the recent successful Atlas-B firing, announced officially that interchangeable nose cones for Atlas and Thor, developed by GE's Missile and Ordnance Systems Dept., would go into production in the near future.

• The Naval Powder Factory recently began delivering Talos solid propellant boosters. The booster, one of the largest in production, was designed and developed by Hercules Powder's Allegany Ballistics Lab.

• Contractors for major subsystems of the Army's Pershing missile: Thiokol, solid rocket motors; Eclipse-Pioneer Div. of Bendix, inertial guidance; Bulova, fuzing and arming; and Thompson Products, transporter-erecter-launcher.

• Dollar Dept.: Orders and payments for missiles amounted to more than $10 billion during the first 11 months of fiscal 1958.

INDUSTRY

• Announcement that GM, Thiokol and Callery Chemical have joined forces in the field of astronautics epitomizes current trend of the industrial community to consolidate allied technologies in competing for major missile and space projects. The agreement, possible forerunner of others designed to weld loosely knitted "teams" into permanent groupings, pools experience of GM with air-breathing engines, guidance systems and missile subsystems; of Thiokol with solid and (through recent acquisition of RMI) liquid-propellant engines; and of Callery with high-energy boron-based fuels for ramjets and rockets.

• If recommendations of committee headed by Guy Stever to study AF R&D

programs are followed, contractors will receive higher fixed fees—closer to the 15 per cent limit than the current average of 7 per cent—on R&D contracts if work performed is up to snuff. The committee suggests that AF technical competence is least adequate in missile-electronics area, where half the R&D funds go, feels this might be overcome by providing more authority and responsibility to qualified civilian personnel and additional opportunities for AF personnel to improve their technical qualifications.

SPACE TALK

• MIT's Guy Stever, chairman of the NACA Space Technology Committee and an excellent bet for a high NASA post, recently pointed up two serious problems facing this country in its drive for an adequate astronautical program—the tendency on the part of the government to centralize authority and distrust working levels, and the need for providing sufficient funds now and long-term support.

• Theodore von Kármán sees no reason why existing aeronautical research groups and industrial labs cannot carry out basic astronautical research, with the aeronautical industry undertaking the design of prototypes and production of standardized space vehicles in much the same manner as they developed new vehicles for flight in the atmosphere.

• Meanwhile, the Air Force, slapped down several months ago for "premature" establishment of a space flight department, did it again, with Brig. Gen. Homer A. Boushey, named to the new post of Director of Advanced Technology, slated to head up AF space developments while working closely with ARPA.

RESEARCH

• Graphite coatings, pointing the way to high-temperature nuclear engine performance, have been developed by 3M's Central Research Lab. Test specimens have withstood temperatures of 1800–2700 F for several hundred hours without measurable oxidation, do almost as well in steam or CO_2.

• NSF will speed dissemination of government research data through a clearing house which will pool its own resources and those of the Library of Congress, the Commerce Dept.'s Office of Technical Services and possibly ASTIA.

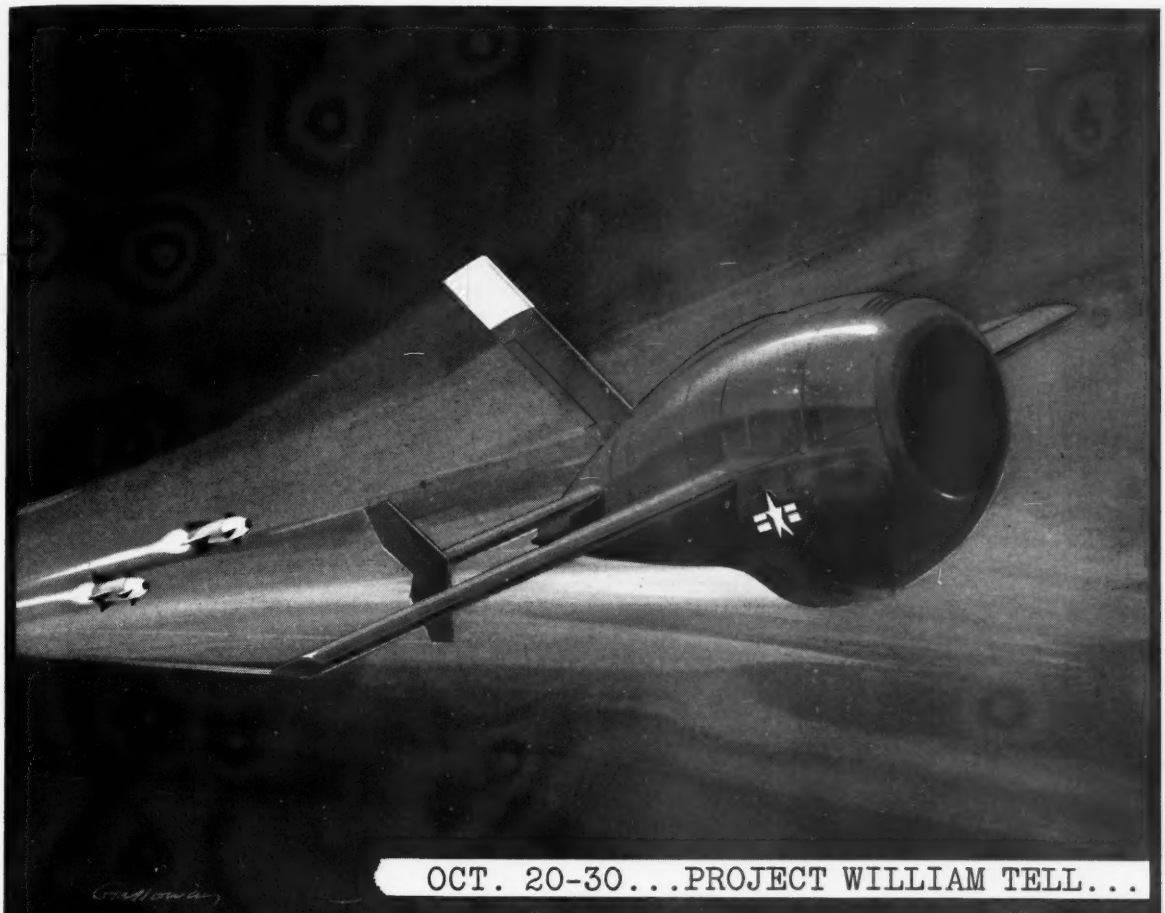
• Taylor Fibre Co. has developed a composite laminated plastic which preliminary tests indicate holds great promise for use in missile nose cones. At surface temperatures of 2000 F, the material is said to conduct about 25 per cent less heat from surface to interior than the most effective homogeneous material.

NASA

• To direct the newly-established National Aeronautics and Space Administration, the White House selected Thomas Keith Glennan, 52, president of Case Institute, Cleveland, chairman of the Institute of Defense Analyses, and former member of the Atomic Energy Commission (1950–52). NACA director Hugh Dryden has been nominated as deputy director of NASA. Dr. Dryden had been in line for the top job, but congressional opposition to his appointment to that position had mounted steadily since spring, with prominent lawmakers objecting that he was "too conservative" to head NASA. Swift Senate confirmation of both appointments was expected.

BUDGET

• Congress sent a record $39.6 billion military appropriation to the White House. The measure includes $815 million more than the Administration had requested—mainly extra funds for the construction of six Polaris submarines in addition to the three already authorized. House and Senate conferees dropped some $440 million in extra funds voted by the Senate—mainly for B-52 bombers and tankers—but the final total was still a $1.2 billion more than the House originally voted.



RYAN FIREBEES TEST AMERICA'S AIR DEFENSE IN FIRST WEAPONS MEET TO USE JET TARGETS

Ryan Firebees are the exclusive flying "bull's-eyes" for the Air Force Project "William Tell"—first weapons meet to use free-flying jet targets. 100 Firebee jet drones will test the pilots, planes, and missiles of America's air defense system under the most realistic "combat" conditions ever achieved.

Firebees will not only draw the fire of the nation's crack Air Force pilots: they will score the results in mid-air with a new electronics system. A running record of hits, misses, and near-misses will be instantly transmitted from Firebees to scorekeepers on the ground. Other Firebees will photograph missiles boring in—or streaking away if they don't score a "hit."

Pitted against the Firebees in this world-wide weapons meet will be the top Air Defense Command squadrons, flying Convair F-102, Northrop F-89J and North American F-86L interceptors. They will fire deadly Falcon guided missiles, and Genie and "Mighty Mouse" rockets.

Only the Firebee—the most advanced target drone—has the high performance, reliability, and extended duration needed for realistic weapons evaluation. In service with the Air Force, Navy, and Army, Firebees are flying in greater numbers and for more hours than any other jet target drone.

The Firebee is another outstanding example of Ryan skill in blending aerodynamics, propulsion, and electronics knowledge to produce a superior product.

RYAN BUILDS BETTER

AIRCRAFT • POWER PLANTS • ELECTRONICS

Ryan Aeronautical Company, San Diego, Calif.

One Pound Lighter—
10 Miles Farther

The problem is—how do you get them lighter?

The missile man's rough rule of thumb, "one pound lighter—10 miles farther," cogently points up the importance of miniaturization in increasing missile range and performance.

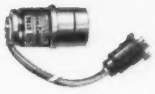
The successful miniaturization of any given component, however, is limited by a manufacturer's ability to produce the given component uniformly and in quantity.

In the seventeen years Honeywell has been designing and producing airborne control systems, miniaturization techniques have received unremitting attention. Special production and quality control techniques have been developed. Laboratory control methods have been applied to production lines to achieve desired product uniformity and quality.

One recent miniaturization achievement at Honeywell is the famous Gnat Gyro—a complete flight control rate gyro weighing only 3.8 ounces. Another, the new Honeywell Miniature Integrating Gyro (MIG) weighs only 8 ounces. The gyro it replaces weighs 100 ounces—a 92% reduction!

In a completely different area, Honeywell has developed a Transistor Power Converter, the size of a candy bar, and weighing 12.1 ounces. It replaces dynamotors five times as large, weighing 5 pounds—yet it delivers the same performance in transforming one DC voltage to another.

Miniaturization is another area where Honeywell's accomplishments make it a logical choice for further missile systems development and production. If you have a problem in the design of systems or components for aeronautical control, call or write Honeywell, Military Products Group, 2753 Fourth Avenue, South, Minneapolis 8, Minnesota.



Gnat Gyro—flight control rate gyro. wt.: 3.8 ounces

MIG Gyro—Miniature Integrating Gyro. wt.: 8 ounces

"Candy Bar" Converter—Transistorized Power converter. wt.: 12.1 ounces

Honeywell

H HONEYWELL *Military Products Group*

Capital wire

News highlights from Washington

MAN IN SPACE

• NASA has earmarked $30 million of its fiscal '59 funds for the man-in-space program. Bulk of the money—$19.5 million—will be used for procurement of Thor boosters for five model flights with animals, followed by two Atlas boosters for full-scale space capsule flights suitable for man. NASA believes it can develop a 2200-lb conical capsule which can sustain a man for several earth revolutions in a 120-mile orbit. Capsule would have a high-drag shape, a tailored couch for the man, a battery of retro-rockets to initiate descent and a parachute for release at 25,000 ft to ease the landing. An Atlas without additional stages could place the capsule in orbit—possibly within two years.

MISSILES

• The crash program to achieve an operational ICBM by 1960 passed another milestone early in August. The Air Force succeeded in firing a fully-powered Atlas 2500 nautical miles down the Cape Canaveral range. Unlike previous tests using only the outside pair of booster engines, the Atlas employed both boosters and the sustainer motor to produce the design takeoff thrust of 360,000 pounds.

• A less spectacular but no less important ICBM breakthrough was disclosed by Maj. Gen. Bernard Schriever, BMD commander, with the announcement that American Bosch Arma has been selected to produce a pure inertial guidance for the Atlas. Arma has been developing its all-inertial system for the Titan in competition with a radio-inertial system under development by Bell Telephone and Western Electric. Presumably, Arma will get Titan guidance responsibility as well as Atlas, although GE is still slated to provide radio-inertial systems for the first few Atlas squadrons.

SATELLITES

• Significant micrometeorite data was obtained by the Navy's abortive Vanguard shot of May 27. Because of faulty alignment, the 21.5-lb sphere soared an estimated 2000 miles into space but fell back into the atmosphere without orbiting. Its telemetering recorded for 10 min after third-stage separation, with 17 micrometeorite hits detected during the period. Navy scientists concluded from this that bombardment of the earth by micrometeorites is at least five times greater than previously calculated.

• Later Vanguards will use as a third stage a high-energy solid-propellant rocket which Allegany Ballistics Lab is developing for the AF's Thor-Able lunar probes. The motor is expected to boost Vanguard's payload capability from 21.5 to 50 lb, permitting doubling up of experiments.

• NOTS is working on an air-launched satellite project at China Lake, Calif., which will be able to place lightweight satellites in orbit at relatively low cost. According to one report, the Navy has already made one attempt to orbit a small payload.

NUCLEAR PROJECTS

• Operational objective of the Project Pluto nuclear ramjet is an unlimited-range hypersonic missile so compact it can be hauled by trailer and launched from the average backyard. Key to Pluto's small size is the absence of shielding for its nuclear reactor. Despite this, nuclear experts anticipate little contamination during launching because of the appreciable time required for the accumulation of hazardous radioactive byproducts. AF and AEC plan to operate a test reactor in a 1300 F oven in Nevada to secure high-temperature data, followed by experiments with a scale model of the Pluto ramjet reactor called Tory 2.

• The AEC-USAF timetable for the Project Rover nuclear rocket calls for demonstration of the feasibility of the powerplant by 1962, with a flying prototype requiring another five or six years. Tests with the Kiwi-A reactor will commence this fall, followed by the more advanced Dumbo reactor in late 1960.

• AF and AEC officials looking for lightweight, long-lived auxiliary power for satellites have seized upon a radically advanced thermocouple developed by a Soviet scientist and continued by Westinghouse Electric Corp. Using mixed valence oxides, the thermocouple has already demonstrated an efficiency of 8 per cent and promises conversion rates of 15 to 25 per cent, compared with average thermocouple efficiency of less than 1 per cent. Used with a radioactive heat source or a reactor, the unit will be competitive—though much lighter—than some types of rotating machinery.

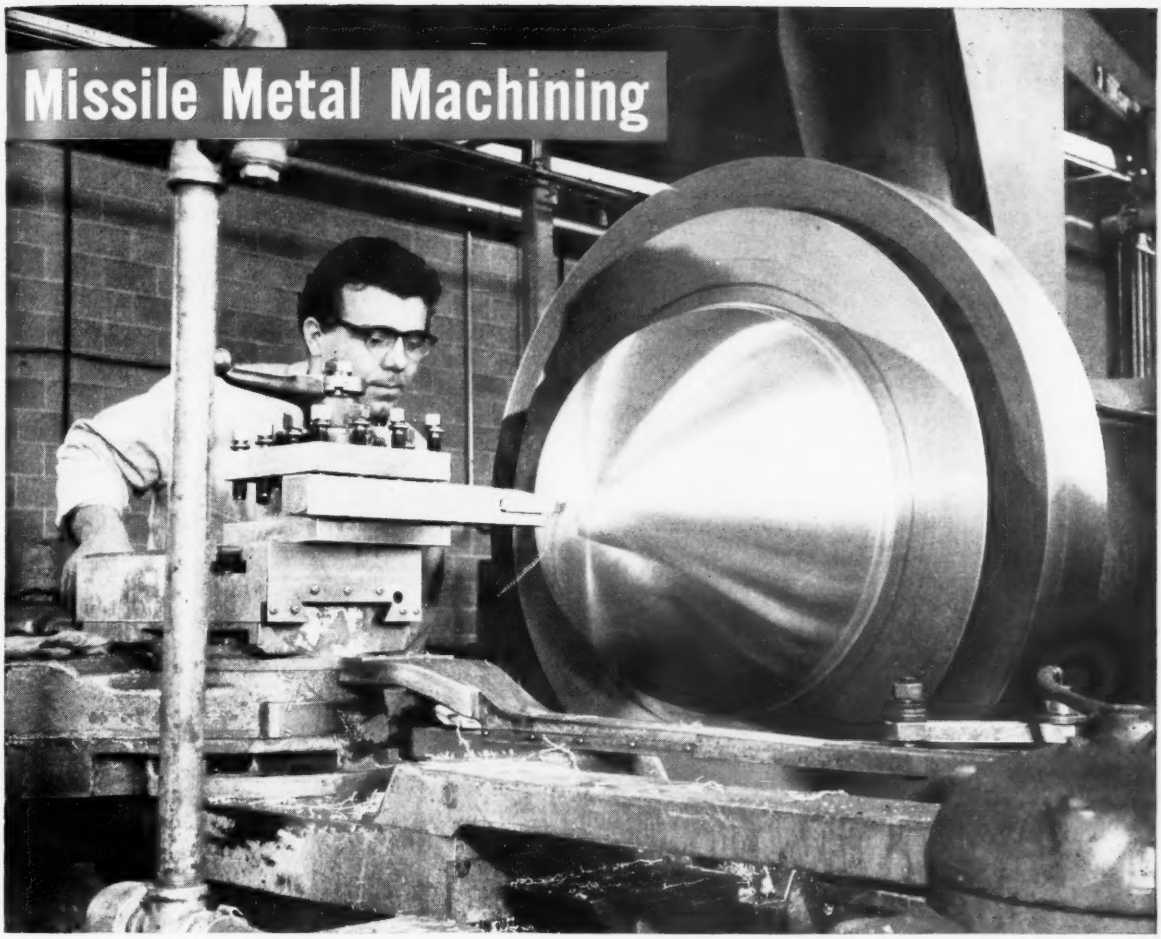
SPACE AGENCY

• NASA will establish a Space Projects Center at Beltsville, Md., with some 640 employes to manage the civilian space program. Congress okayed the new center in authorizing NASA to commence work on $47.8 million worth of new construction projects, including a $24.5 million expansion at the Wallops Island, Va., rocket research station, and $19.5 million to take over the Navy's Minitrack network and expand it with new stations.

• ARPA is growing increasingly unhappy about its "joint" responsibility with NASA for the development of the million-lb thrust rocket engine and the man-in-space program. Although the top level space council established with NASA has not yet ruled on which agency will supervise the two programs, ARPA officials complain that NASA is acting as if it already had the assignments. ARPA men also fear NASA is optimistic as to both the time and money necessary to realize the program objectives.

ANTI-MISSILE

• Using an Army Redstone ballistic missile, the U.S. detonated an experimental nuclear warhead an estimated 100 miles above Johnston Island early in August. The blast was plainly visible in Hawaii, 700 miles to the northeast. A nine-hour Pacific radio blackout was promptly blamed on the explosion, but Bureau of Standards scientists attributed the disturbance to solar flares. Results of the test are of crucial importance to the development of the Army's Nike-Zeus anti-ICBM missile.



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For the record

The month's news in review

July 8—Army plans additional $30 million JPL facility for R&D work on rocket and missile fuels at Camp Irwin, near Barstow, Calif.

July 9—AF successfully launches Thor-Able re-entry test vehicle carrying a mouse some 6000 miles, but fails to recover nose cone.

—Soviet scientists A. Ilyishin and V. Lensky say Russia could launch a space ship at any time with existing fuels and rocket designs.

July 12—First scheduled test flight of AF Atlas ICBM with all three engines operating is canceled just before main-stage fires.

July 13—Special report by a committee of AF scientific advisers, chaired by H. Guyford Stever, MIT associate dean of engineering, urges sweeping expansion and reorganization of AF R&D program, drive to obtain more funds to carry out R&D work.

July 15—Senate-House conferees create compromise NASA bill, giving the President, as head of a nine-man advisory council, overriding powers.

July 16—House and Senate okay compromise NASA bill.

July 17—Army recovers full-scale nose cone of Jupiter missile after successful 1500-mile flight.

July 19—First three-engined Atlas breaks apart two minutes after firing due to malfunction in control system.

July 20—ARPA chief scientist Herbert F. York says U.S. has rocket capable of sending simple communications satellite around the moon, but that space rocket with million-lb thrust is still five or more years off.

July 23—AF successfully launches Thor-Able mouse-carrying vehicle over full 6000-mile course, but again fails to locate nose cone.

—Senate sets up 15-member Committee on Aeronautical and Space Sciences with jurisdiction over NASA. House is setting up similar committee.

—House and Senate approve resolution favoring a ban on use of outer space for military purposes.

July 25—AF awards Rocketdyne contract to develop million-lb thrust liquid rocket engine.

July 26—Army orbits Explorer IV, weighing 38.43 lb and instrumented to measure radiation belt discovered by earlier U.S. satellites.

—AF Thor breaks up shortly after launching.

—Capt. Iven C. Kincheloe Jr., slated to test the X-15, dies in jet crash at Edwards AFB.

July 27—Two Navy balloonists, M. Lee Lewis and Comdr. Malcolm Ross, set new record of 34 1/2 hours in the air.

July 28—Senate committee hits AF for allowing duplicate test facilities to be built by private contractors while Government-owned facilities remain idle.

—Use of satellites to monitor an agreement to suspend nuclear weapons testing is proposed by East-West scientists meeting in Geneva.

July 29—President Eisenhower signs NASA bill.

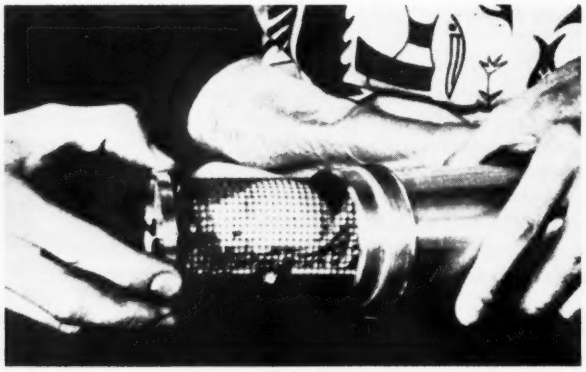
July 30—President asks congress for initial $125 million for NASA, to be combined with $117 million DOD has transferred to it.

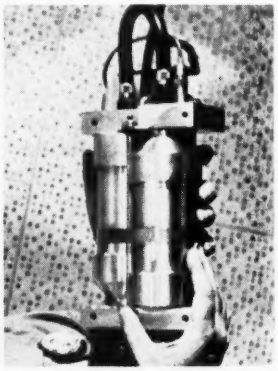
—Unmanned AF balloon, out to break altitude record of 133,000 ft, collapses at 40,000 ft.

July 31—Natl. Academy of Sciences-Natl. Research Council forms 16-man Space Science Board.

—Russians reveal first detailed satellite data at IGY meeting in Moscow.

—Anti-secrecy bill goes to White House.





Mighty Mouse **Prepped for launching into space in second Thor-Able rocket, white mouse, dubbed Wickie, sips water inside glass container (left). In center photo, mouse, in swiveling cage containing dehydrated food, is placed in a canister, and then (right) loaded into its air-conditioned home before actually going into nose cone.**

...speaking of

Missile Ground Support **MOBILITY**

NO JOB'S TOO TOUGH—WE DELIVER ON SCHEDULE

Take the case of the U.S. Air Force's (IRBM)—THOR missile project. FMC's design engineers developed the transporter-erector and launcher portion of the ground support equipment with Douglas Aircraft Company, Inc., prime contractor. The first units were engineered, manufactured and delivered in just eight months—2 months ahead of schedule.

FMC is not looking for "crash programs," but when the need arises, we go all out to meet deliveries. The delivery deadline for the THOR transporter-erector, launching base, and power-pack trailer was met because FMC handled the complete project—design, engineering, and production—with experienced people, at a single facility devoted exclusively to military equipment production. *Consult with FMC at the initial stage of project planning.* Contact us today for full information.

Creative Engineers: Find stimulating challenge at FMC's Ordnance Division.

Missile equipment takes to the air in Air Force's giant C-133 transport which flew FMC-built Thor ground support equipment from West Coast to test site at Cape Canaveral, Florida. First load (upper) takes 65' launcher-erector section. Launching base and power-pack trailer (above) were flown in a second shipment.

Putting Ideas to Work

FOOD MACHINERY AND CHEMICAL CORPORATION
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Missile Equipment Section 2-F
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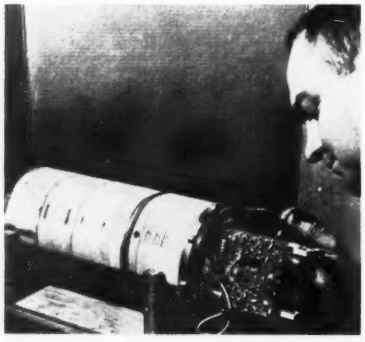
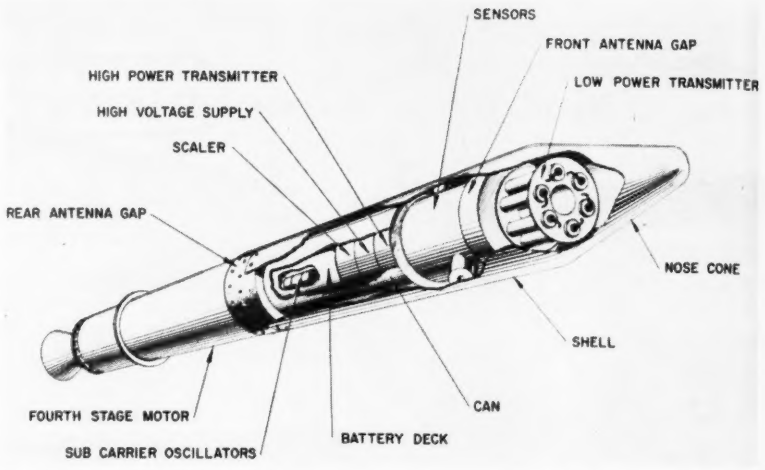
Explorer IV Joins Explorer I, Vanguard I and Sputnik III

Explorer IV, instrumented solely to probe an intense belt of radiation detected at altitudes of 600 miles and higher by earlier satellites, was launched into orbit by the Army on July 26 under ARPA direction. The satellite became the third U.S. vehicle circling the earth, along with Explorer I and Vanguard I. Only Russia's Sputnik III now shares the same space. Although the heaviest of U.S. satellites to date, weighing 34.43 lb, Explorer IV is far underweight compared to the Sputniks. The added weight was made possible by the improvement of solid fuels in the two upper stages of the Jupiter-C launching vehicle.

The Naval Research Lab placed Explorer IV's apogee at 1386 miles and perigee at 178 miles from the earth, while radio trackers reported that it was orbiting on a regular 110.2-min schedule. The satellite's orbit lies between 51 deg N latitude and 51 deg South, farther north and south than its predecessors, which had not gone beyond 33 deg N.



Instrumental heart of Explorer IV is examined by research assistant Carl McIlwain of the State Univ. of Iowa, which developed the radiation package.



Cutaway diagram shows equipment and instrumentation of Explorer IV, biggest U.S. satellite launched to date.

Except for its instrumentation, Explorer IV is much like its forebears, which paved the way for the specially designed radiation package now measuring the powerful radiation that earlier had jammed the Geiger counters of Explorers I and II. Explorer IV's instrumentation consists of two Geiger and two scintillator counters, and two radio beacons designed to transmit continuously on 108 and 108.03 mc. The Geiger counters are measuring radiation inside the satellite; the scintillators, outside bombardment.

Whereas previous satellites reported only the gross amount of radiation encountered, Explorer IV is handling not only a far greater range of cosmic ray data, but is able to differentiate between the energy levels of the rays striking the counters. Thus the data will not only show the total number of particles but also what fraction falls within certain preselected energy ranges. The information may help reveal the precautions and safeguards needed for space travel.

NAS Establishes 16-Man Space Science Board

The National Academy of Sciences-National Research Council has established a 16-member Space Science Board "to survey . . . the problems, opportunities and implications of man's advance into space." Lloyd V. Berkner, president of Associated Universities, Inc., president of the International Council of Scientific Unions and an NAS member, has been named chairman of the board.

In addition to acting as the focal point for all NAS-NRC activities connected with space research, the board will coordinate its work with appropriate civilian and government agencies, particularly NASA, NSF and ARPA, as well as with foreign groups active in this field.

Eleven ad hoc committees have already been formed to carry on the board's work. The committees, along with chairmen and vice-chairmen, who comprise the board's membership, are:

Geochemistry of space and exploration of the moon and the planets—Harold C. Urey, UCLA, chairman; Harrison S. Brown, Cal Tech, vice-chairman.

Astronomy and radio astronomy—Leo Goldberg, Univ. of Michigan, chairman.

Future vehicular development—Donald F. Hornig, Princeton Univ., chairman.

International relations—W. A. Noyes, Univ. of Rochester, chairman.

Immediate problems—R. W. Porter, consultant, General Electric Co. and chairman of the USNC-IGY Technical Panel on Earth Satellites, chairman.

Space projects—Bruno B. Rossi, MIT, chairman.

Ionosphere—A. H. Shapley, National Bureau of Standards, chairman.

Physics of fields and particles in space—John A. Simpson, Univ. of Chicago, chairman; James A. Van Allen, Iowa State Univ., vice-chairman.

Future engineering development—O. G. Villard Jr., Stanford Univ., chairman.

Meteorological aspects—Harry Wexler, U.S. Weather Bureau, chairman.

Psychological and biological research—H. Keffer Hartline, Rockefeller Institute for Medical Research, chairman; S. S. Stevens, Harvard Univ., vice-chairman.

A 12th committee, on geodesy, will be chaired by a board member still to be selected.

Hugh Odishaw, who also serves the NAS-NRC Council as executive director of USNC-IGY, has been named executive director of the board, which will have a permanent staff to serve as a secretariat.

NEW AiResearch steering control system

Combines Acceleration Switching Valves And Hydraulic "Printed Circuit"

More reliable and responsive... this lightweight electro-hydraulic steering control system converts low-level electronic signals from the main guidance system into hydraulic energy which actuates the mechanisms steering the missile.

Packaged as an integrated unit, the three servo valves and six control actuators are mounted on a common manifold and powered by fluid or hot gases. The simplified "printed circuit" system of integral passageways within the manifold eliminates all external plumbing and leakage.

The acceleration switching servo valves provide positive control of spool velocity, thereby achieving greater resolution, reliability and response even at extreme temperatures.

Easily installed and removed as a complete, interchangeable unit, acceptance testing of this compact system can be accomplished prior to missile installation. Suggested applications are: missile surface controls, jetavator controls, and vector and nozzle steering controls. Your inquiries are invited.

Specifications

Actuator load (range)	*90 to 150 in. lbs.*
Electrical input (nominal)	*28 volts DC—10 Milliamperes*
Pressure range	*500 to 3000 psi*
Rated flow	*½ to 2 gpm*
Mounting	*Manifold*
External leakage	*None*
Proof Pressure	*4500 psi*
Burst Pressure	*7500 psi*
Temperature operating range	
Fluid	*-65 F to 450°F*
Ambient	*-65°F to 750°F*
System filtration	*10 microns*

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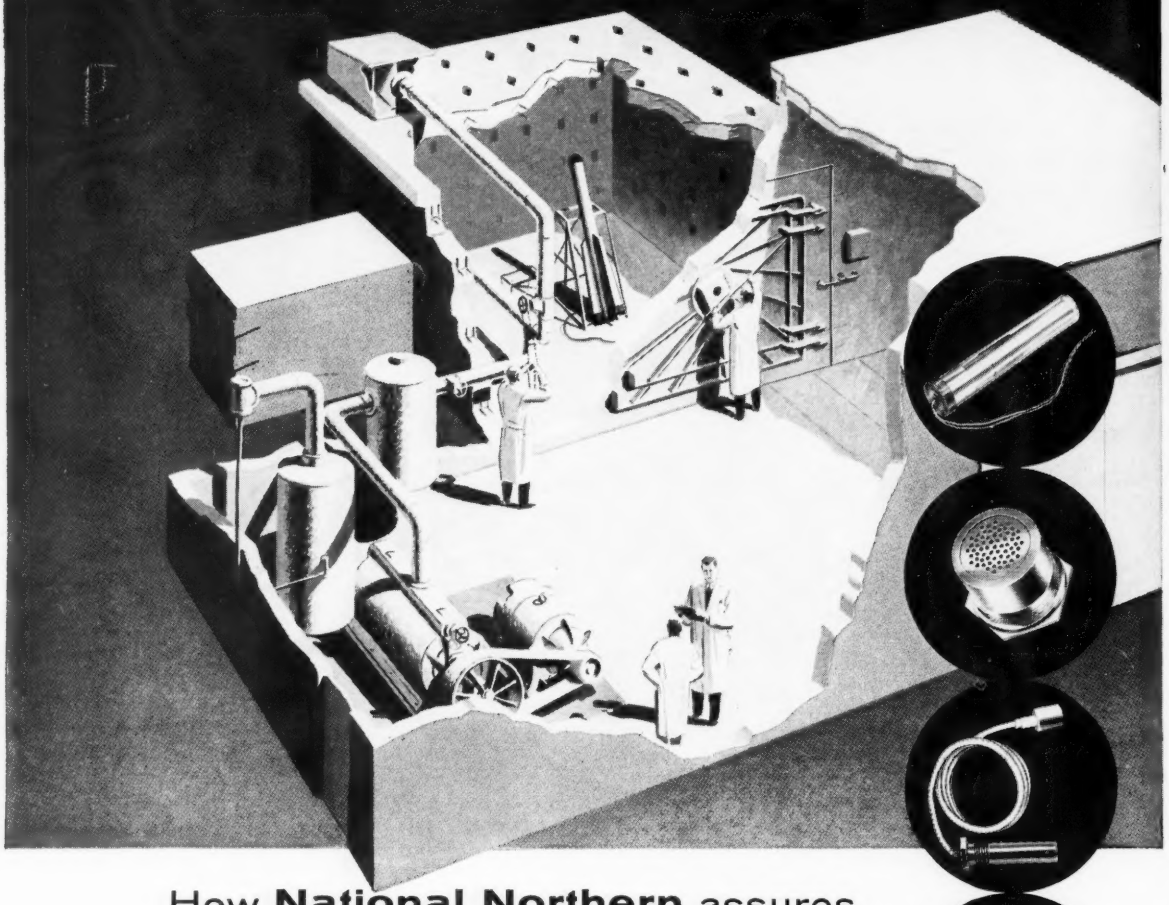
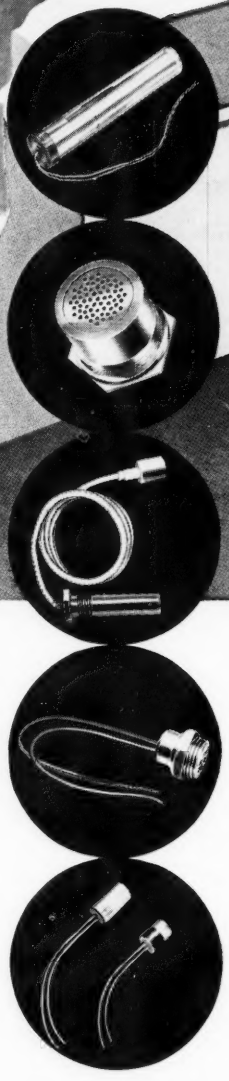
SETTING THE STAGE FOR RELIABILITY IN OUTER SPACE





How **National Northern** assures dependability in high altitude performance of ignition devices, pyrotechnics, and explosive components.

As depicted here by the artist, National Northern technical experts prepare their high altitude test chamber built in cooperation with the U.S. Navy, for surveillance studies to determine how extremes of temperature and pressure affect the performance of explosive charges. Through exhaustive environmental tests like these, National Northern Division of American Potash & Chemical Corporation can assure you of "built-in reliability" for the vital performance of propellants for rockets and missiles, explosives, pyrotechnics, detonators, igniters, squibs, gas generators, fuses, and related items. Years of experience in research, development, and production of literally thousands of these components for leading defense and commercial customers is the reason why National Northern should be your first choice for a solution to your problems in the design and production of packaged pyrotechnic and explosive components. Write today for your copies of National Northern's current technical bulletins and facilities brochure—"Missile and Rocket Power Technology." Address National Northern Division, American Potash & Chemical Corporation, P. O. Box 175, West Hanover, Massachusetts.

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National Northern's current fields of activity:

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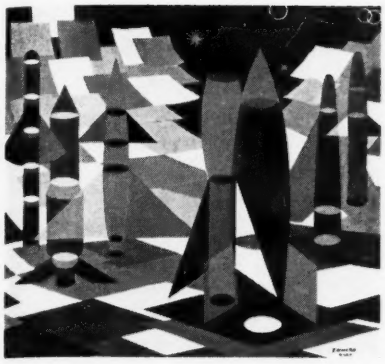


COVER: *"Space Chessboard," a symbolic depiction of the world today, poised for an all-out assault on space, painted by Edward Ryan.*

Astronautics

SEPTEMBER 1958

The Stars Draw Closer

Some time ago, ARS proposed the establishment of a new agency to take over long-term planning of a national astronautical program (January, 1958, ASTRONAUTICS, pages 18–28). On July 29, the President signed an act bringing the National Aeronautics and Space Administration into being. We now have, for the first time, a civilian agency dedicated to the development of an astronautical technology and, in the not-too-distant future, of the vehicles that will take us to the stars.

In basic concept and principle, the new agency is similar to that proposed by ARS even before the launching of the first earth satellite. It is unfortunate that it has taken us nine months to create such an agency; it is to be hoped that turning it into a functioning organization will take considerably less time.

At the moment, we do not have a national space flight policy, a set of specific astronautical objectives or even an exact definition of the tasks to be performed by NASA. These must be evolved with all possible speed.

It is gratifying to learn that, under the act which brought NASA into being (see page 39), the President himself will play a key role in determining the policies, objectives and programs that will go to make up the U.S. space flight effort. That astronautical policy will henceforth be decided at such a level is indeed significant.

Since space flight, by its very nature, is international in scope and will benefit all mankind, it is to be hoped that our national policy, when it comes into being, will do more than merely pay lip service in this direction. The presence of the Secretary of State on the NASA Council is certainly a hopeful indication.

Establishment of NASA is, as the President said in signing the act which brought it into being, a "historic step." To those of us in the Society, July 29 is even more, representing, as it does, another relentless stride toward the goal recognized by the ARS founding fathers, who, almost 30 years ago, had the foresight (some called it the effrontery) to name their newly formed organization "The American *Interplanetary* Society."

George P. Sutton
President, AMERICAN ROCKET SOCIETY

Optimum paths to the moon and planets

Space ships wending their way to the moon, Mars and Venus will follow trajectories designed to make the most of the fuel used, gravitational forces and relative motions of the planets

By Arthur E. Bryson, HARVARD UNIVERSITY, CAMBRIDGE, MASS.
Gerald A. Ouellette, RAYTHEON MFG. CO., WALTHAM, MASS.

Arthur E. Bryson is an associate professor of mechanical engineering at Harvard University and consultant to the Raytheon Missile Systems Division. Dr. Bryson received his B.S. in aeronautical engineering at Iowa State College and his Ph.D. in Aeronautics at the California Institute of Technology. He was an aviation maintenance officer in the Navy during World War II, and from 1950 to 1953 was in the aerodynamics department of the Hughes Guided Missile Laboratory.

Gerald A. Ouellette, a member of the aerodynamics group at the Raytheon Missile Systems Division, is engaged in aerodynamic studies of rocket-propelled guided missiles. He received his A.B. in physics at Harvard University and did graduate work there in mechanical engineering before joining Raytheon.

THE WORD "OPTIMUM" tends to be used somewhat loosely. We even heard the other day of a young engineer who told his boss he had an idea that would make a certain design "more optimum." To be precise in speaking of optimum paths, we should say (1) what it is that is optimum about them and (2) what the ground rules (constraints) are for determining this optimum.

We can begin profitably with a term basic to rocketry—payload ratio, defined as initial gross weight divided by payload weight. We would like to minimize payload ratio in most rocket paths between two points. Sometimes, however, the problem becomes easier to solve if instead we try to minimize *mass ratio,* defined as initial gross weight divided by final or "all-burnt" weight. The difference, of course, lies in the amount of structure included in the final weight.

Since a large fraction of a rocket's takeoff weight is fuel, a great deal of the fuel must produce thrust simply to hold up the unburned fuel, and still more to accelerate it. For this reason it is desirable to burn fuel as rapidly as possible, converting it into kinetic energy of the vehicle, which will be exchanged for potential energy in the earth's gravitational field as the vehicle moves away from the earth. In fact, if it were possible, we would like to burn the fuel instantaneously, giving the vehicle an impulse, i.e., an instantaneous charge in speed. This statement must be modified if we consider atmospheric drag on the vehicle, because the high velocity associated with an impulse start wastes fuel in overcoming drag.

The best compromise involves using some fuel for an instantaneous velocity charge—as rapid as possible in the practical case—and then burning fuel at a lower rate for a short time thereafter. For a single-stage vehicle, this optimum requires maximum thrust until the gravitational pull of the earth on the vehicle, W, is equal to $(1 + v/c)D$, where D is the vehicle drag, v is velocity, and c is the specific impulse of the propellant (identical to the exhaust velocity of the propellant gases). Thrust adjusted to maintain this equality gives continuous vertical acceleration until escape or other desired velocity is attained. This simple relation is only valid if the drag is proportional to the square of the velocity. The more general relation is $W = v\,\partial D/\partial v - (1 - v/c)D$.

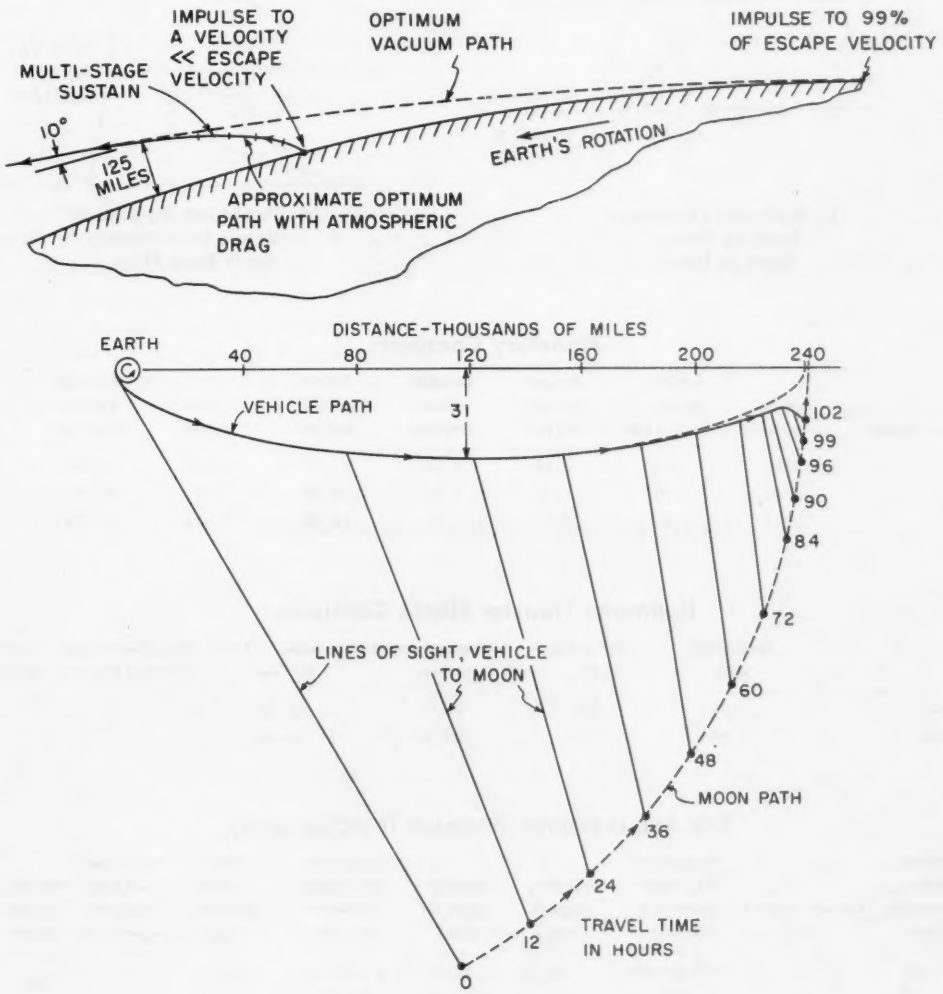
The path of least fuel expenditure between two co-planar circular orbits about a gravitational center was given by Hohmann. The

path involves two impulses, one at the beginning and one at the end, the path itself being an ellipse tangent to both orbits, with the gravitational center at one focus, as shown in the top illustrations on page 21. The optimum transfer between co-planar, co-focal elliptic orbits does not appear to be so neatly solved as yet. D. Lawden has shown that two-impulse is better than one-impulse transfer for two equal intersecting elliptic orbits, and that the transfer orbit is almost tangent to both orbits. With economical use of fuel the aim, it appears best to apply impulses tangent to, or at least nearly tangent to the path.

The determination of an optimum path between earth and the moon is considerably more complicated than for orbit-to-orbit transfer, because consideration must be given to the earth-moon gravitational fields, the earth's atmosphere, the moon's motion about the earth, and the earth's rotation about its axis. Of lesser importance in determining the optimum thrust program, but important to precise determination of the path for navigation, are gravitational effects of the sun, inclination of the moon's orbit to the ecliptic, and inclination of the earth's axis to the ecliptic.

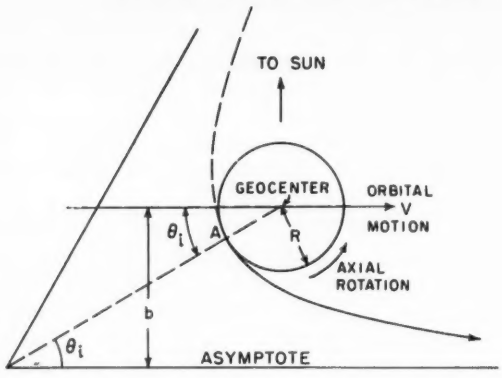
Transfer from a close satellite orbit about the earth to the more distant satellite orbit of the moon is best made by a Hohmann ellipse. This will probably be the way large payloads will be sent to the moon, using the technique of orbital refueling in

OPTIMUM PATHS FOR EARTH-MOON FLIGHT

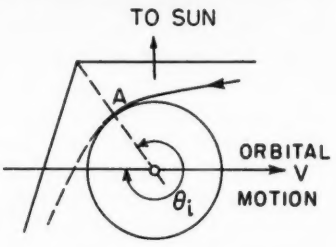


Note: There are no acceleration limits in the departure from earth. The path is pictured in terms of a nonrotating geocentric coordinate system.

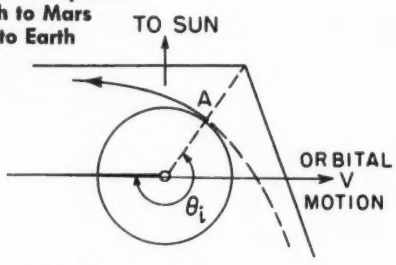
Hyperbolic Approach and Departure Paths in Planetary Coordinates



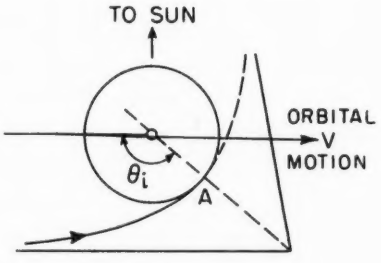
(a) Perihelion Departure
Earth to Mars
Venus to Earth



(b) Aphelion Departure
Mars from Earth
Earth from Venus



(c) Aphelion Departure
Earth to Venus
Mars to Earth



(d) Perihelion Approach
Venus from Earth
Earth from Mars

Planetary Constants

Planet	Symbol	Radius (mi)	Surface gravity (⊕ = 1.00)	Escape velocity (mi/sec)	Circular velocity (mi/sec)	Orbital velocity (mi/sec)	Orbital radius	Angular velocity (deg/day)	$\mu = g_0 R_0^2$ (mi^3/sec^2)
Venus	♀	3790	.845	6.46	4.57	21.75	0.723	1.606	74,460
Earth	⊕	3960	1.00	6.95	4.92	18.50	1.00	0.986	95,630
Mars	♂	2110	1.41	3.13	2.21	14.98	1.524	0.524	10,320

Hohmann Transfer Ellipse Constants

Trip	Semi-major axis	Half-period days	Perihelion velocity (mi/sec)	Aphelion velocity (mi/sec)	Perihelion transfer increment (mi/sec)	Aphelion transfer increment (mi/sec)
Earth-Mars	1.26	259	20.38	13.36	1.88	1.62
Earth-Venus	0.86	146	23.49	16.96	1.69	1.54

Trip Requirements (Vacuum Impulse Case)

Trip	Initial velocity increment (mps)	Launch* angle Θ_i (deg)	Departure* Asymptote distance b (kilomiles)	Planetary angle Ψ (deg)	Approach* angle Θ_i (deg)	Approach* asymptote distance (kilomiles)	Final velocity increment (mps)	Ideal total velocity requirement (mps)	Waiting period (days)	Total trip time (days)
Earth-Mars	7.21	29.3/32.2	15.2/17.1	44.4	322/321	6.16/6.39	3.52 /	21.5	455	973
Mars-Earth	3.52	218/219	6.16/6.39	−75	153/148	15.2/17.1	7.21 \			
Earth-Venus	7.08	204/207	18.3/20.6	−54.5	151/148	14.6/16.4	6.71 /	27.6	465	757
Venus-Earth	6.71	29.2/32.2	14.6/16.4	36	336/333	18.3/20.6	7.08 \			

* Surface departure or arrival/Satellite departure or arrival ($R = {}^{5}/_{4}\ R_0$).

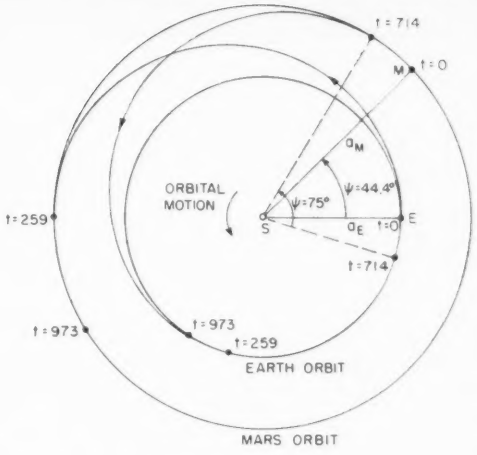
the close satellite orbit. It is not so clear that the Hohmann ellipse is optimum for a direct journey from the earth's surface to the moon. If the earth were not rotating, the "straight shot" radially outward would give a very slight (0.1 per cent) advantage over the ellipse. However, using the surface speed of the rotating earth at the equator saves roughly 0.25 mps and clearly gives the advantage to the ellipse.

Multistage Vehicle Must Be Used

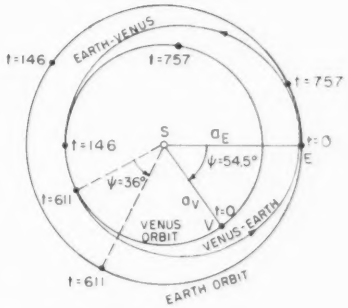
With present fuels and structural ratios, this direct shot must be a multistage affair. For a given number of stages, optimizing the multistage rocket in a vacuum is quite a problem in itself, involving a succession of impulses, which are, of course, not attainable practically. Very little work has been done for the case with drag, but the answer would probably still involve impractically high accelerations. If the structural ratio of all steps is the same, velocity increments of all stages should be equal (in the vacuum case).

The velocity necessary to get to the moon is only 1 per cent less than escape velocity, namely, 6.89 mps. Thus, the Hohmann ellipse near the earth looks almost identical to the parabola for escape. The path to the moon is shown by the two illustrations of paths on page 19. Because of the atmosphere, the optimum path will obviously not start off tangent to the earth's surface. In fact, it probably starts off almost vertically (CONTINUED ON PAGE 80)

Paths for Round Trips to Mars and Venus



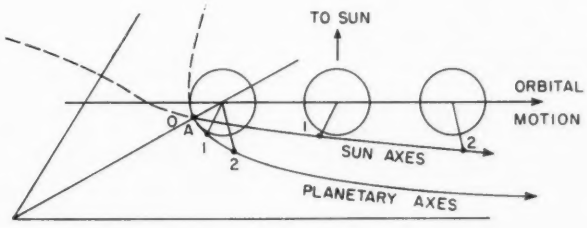
(a) Earth-Mars-Earth



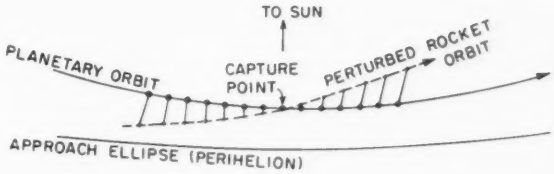
(b) Earth-Venus-Earth

Note: Transfer ellipses between planetary orbits show boundary conditions and elapsed times. Relative positions of planets are to scale.

Perihelion Departures in Sun Coordinates



(a) Departure



(b) Approach

What do you know about space?

Here's a chance to match your own knowledge of astronautics against that of students registered for the U. of California's Space Technology Course

At the conclusion of the Space Technology course recently conducted by the Engineering Extension Division of the University of California, some 850 of the 5500-plus students who took the course showed up to take the final examination prepared by the more than 30 top experts who participated in the statewide lecture series.

Through the good offices of Howard S. Seifert of Ramo-Wooldridge Corp., statewide coordinator of the course, ASTRONAUTICS has obtained a copy of the exam, which originally consisted of only 85 questions. It has been expanded here to 102 questions to take in some which did not arrive in time for inclusion in the original exam.

Dr. Seifert notes in a recent letter that most of the questions are difficult, even though multiple choice, since each of the lecturers seems to have dreamed up three or four very subtle questions for the exam. This, plus the fact that students had neither homework nor a full text to work from, may account for the relatively low scores on the original 85-question exam. Highest score registered was 68 right, while the mean score was 45 right.

Here's a chance to match your score against those obtained by students taking the course. The answers will be printed in next month's ASTRONAUTICS.

—I.H.

1. To achieve maximum range for a point mass missile on a flat earth (uniform gravitational field) in vacuum, the thrust attitude angle, $\psi(t)$, relative to the horizontal, should follow a program of the form:

   (1) $\psi(t) = 45°$; (2) $\psi(t) = at + b$; (3) $\psi(t) = \tan^{-1}(at + b)$; (4) $\psi(t) = b$; (5) $\psi(t) = \tan^{-1}(at + b)/(ct + d)$ where a, b, c, and d are all nonzero constants

2. For a point mass missile, whose initial velocity v_0 is nonzero and nonvertical, a gravity turn trajectory may be achieved by keeping:

   (1) the net force on the missile always horizontal; (2) the thrust attitude angle, $\psi(t)$, constant throughout the flight; (3) the velocity vector always inclined at 45° to the horizontal; (4) the thrust vector at time t always parallel to the initial velocity vector, v_0; (5) the thrust vector at time t always parallel to the velocity vector at time t

3. A single-stage point mass missile with constant thrust and mass flow rate is flown on a typical gravity turn trajectory in vacuum in a uniform gravitational field. If the initial kick angle, β_0, is increased enough to increase the velocity attitude angle at burnout, β_1, by about 10% (both β_0 and β_1 being measured with respect to the vertical), one would find that the velocity magnitude at burnout, v_1, had:

   (1) increased by more than 10%; (2) increased by less than 10%; (3) decreased by more than 10%; (4) decreased by less than 10%; (5) decreased by about 10%

4. For a vacuum trajectory of a point mass missile in a uniform gravitational field, programming the thrust attitude angle (with the horizontal), $\psi(t)$, according to $\tan\psi = a - bt$ will, with appropriate choice of the constants a and b, make stationary *any* function of the following burnout quantities:

   (1) v_x, v_y, y; (2) v_y, x, y; (3) v_x, v_y, x; (4) v_x, x, y; (5) v_x, v_y, x, y

5. A two-body orbit may be completely described by a set of elements whose number is:

   (1) 3; (2) 6; (3) 8; (4) 10; (5) 12

6. The accuracy of one micrometric telescopic observation is one part in:

   (1) 10; (2) 10^2; (3) 10^3; (4) 10^6; (5) 10^{10}

7. Which of the following does not directly influence the path of an earth satellite in inertial space?

   (1) rotation of the earth; (2) Jupiter; (3) drag; (4) the sun; (5) equatorial bulge of the earth

8. One of the following is *not* a proper method of determining the position in a perturbed orbit: Integration of the

   (1) total accelerations; (2) differences between total accelerations and those in a fixed two-body orbit; (3) differences between total accelerations and those in some other fixed reference orbit; (4) kinetic energy; (5) variations of the parameter of a reference oribit.

9. Typical flight time for one-way travel to the moon is:

   (1) 3 minutes; (2) 3 hours: (3) 3 days, (4) 3 months; (5) 3 years

10. A basic mathematical topic useful in analytical treatment of lunar trajectories is:

    (1) Legendre polynomials; (2) Jacobi's integral; (3) Boolean algebra; (4) Bernoulli numbers; (5) quantum mechanics

11. Most accurate initial guidance is required to set up an unpowered trajectory to:

    (1) impact the moon; (2) circumnavigate the moon and return to continental U.S.; (3) establish a lunar satellite; (4) escape from the earth-moon system; (5) detonate an A-bomb on the moon

12. A particle is executing an unpowered trajectory in earth-moon space. Throughout the trajectory, a constant value is maintained for:

    (1) total energy of the particle; (2) total momentum of the particle; (3) both (1) and (2); (4) neither (1) or (2); (5) position of the particle

13. For ion-propelled rockets in which the voltage and beam current can be varied at will (subject only to the restriction that the instantaneous power in the exhaust beam cannot exceed the power available from the primary power source), the instantaneous power in the beam should be:

    (1) varied according to a differential equation derived in the class notes; (2) always kept at its maximum value; (3) kept at a constant minimum value consistent with reaching the target in a given time; (4) kept at its maximum value until a velocity is attained sufficient to coast the rocket to its destination, after which the power should be turned off; (5) kept at its maximum value during certain intervals of time and turned off during well-chosen coast periods

14. For a rocket using the type of propulsion defined in Question 13 and traveling in an arbitrary gravitational field (where U is the potential due to gravity and $\bar{a}$ is the vector acceleration due to thrust), the acceleration program which accomplishes a given mission (time of travel specified and initial and final position and velocity specified) with a maximum payload:

(1) keeps the magnitude of $\bar{a}$ constant; (2) keeps $\bar{a}$ perpendicular to $-\Delta U$, the gravitational force; (3) minimizes the integral of the absolute value of $\bar{a}$; (4) minimizes the integral of the square of $\bar{a}$; (5) directs $\bar{a}$ always along the instantaneous velocity vector

15. For rectilinear motion in field-free space of a vehicle of the type described in Question 13, if a given time is allotted to obtain a given velocity, a maximum payload may be carried if:

(1) the exhaust velocity is held constant; (2) the mass flow rate is held constant; (3) the thrust is held constant; (4) the acceleration due to thrust is held constant; (5) the ion beam accelerating voltage is held constant

16. Of the following ways of escaping from the earth (to the point where the total energy is zero) in a spiral path in a given allotted time, a largest payload may be carried when:

(1) the thrust is held constant and directed circumferentially; (2) the thrust is held constant and directed radially; (3) the thrust is held constant and directed along the instantaneous velocity vector; (4) the acceleration due to thrust is held constant and directed circumferentially; (5) the acceleration due to thrust is held constant and directed radially

17. In a machine computation of the optimum trajectory and acceleration program for a flight to Mars, it was found that there was a period of very low accelerations—a "quasi-coast period." During that period:

(1) the power going into the exhaust beam is turned off; (2) the power going into the exhaust beam is reduced way below its maximum value; (3) the power is somewhat reduced and the mass flow rate also reduced; (4) the power is held constant at its maximum value and the exhaust velocity decreased; (5) the power is held constant at its maximum and the exhaust velocity is increased

18. Strictly speaking, an observer may use the Special Theory of Relativity to describe the motion of objects in his neighborhood if:

(1) he is at rest relative to the laboratory; (2) he is moving with constant velocity relative to the sun; (3) he is in a rocket in which the thrust balances gravity; (4) he is falling freely under gravity; (5) he is in a rocket which is being propelled in a region of space a long way from gravitating matter

19. A hypothetical rocket moves out to a distance of 10 light years and returns, following a programmed flight in which its acceleration is $+g$ for the first and fourth parts of its journey and $-g$ for the second and third parts. On returning to earth, the traveler will have aged approximately:

(1) 30 years less; (2) 30 years more; (3) 3 years less; (4) 3 minutes less; (5) 3 years more

than if he remained on earth

20. If two accurate clocks A and B were synchronized on earth, and then A was launched in a satellite orbit 500 miles above the earth for a year, returned to earth undamaged and compared to B, one would find:

(1) A was slower than B by about 10 millisec; (2) B was slower than A by about 10 millisec; (3) A and B were in agreement due to the canceling of the effects of gravity and the effects of the motion; (4) B was slower than A by about 10 sec; (5) since $v/c \sim 10^{-5}$, the time difference was of the order of 10^{-5} years

21. The chemical rocket as the major braking device for achieving nondestructive landing on a planet is:

(1) impossible; (2) unattractive; (3) acceptable; (4) attractive; (5) required

22. The impacting trajectory for re-entry into the earth's atmosphere of a space vehicle may be acceptable for:

(1) radiation-cooled designs; (2) heat-sink design; (3) manned vehicles; (4) unmanned ablation-cooled vehicles; (5) all vehicles

23. The grazing trajectory can be used to decay a parabolic orbit into a circular satellite orbit without subjecting a space vehicle to excessive deceleration or heating, providing the vehicle is:

(1) light weight; (2) high drag; (3) heavy weight; (4) low drag; (5) accurately guided

24. Maximum decelerations encountered during re-entry from satellite orbit about the earth can be reduced from about 8 g's to between 1 and 2 g's using lift. Maximum equilibrium surface temperatures can be reduced as much as:

(1) 5 F; (2) 50 F; (3) 500 F; (4) 5000 F; (5) 50,000 F

25. The thrust coefficient of a rocket nozzle immersed in the atmosphere:

(1) always increases monotonically as the expansion area ratio ϵ increases; (2) always increases monotonically as the chamber to exit pressure ratio increases; (3) remains constant if ϵ remains constant; (4) remains constant if chamber pressure remains constant; (5) is independent of ratio of specific heats of the gases

26. The most likely value for a rocket nozzle area ratio for space use would be:

(1) 5; (2) 10; (3) 200; (4) 25; (5) $^1/_2$

27. The most likely value for a rocket nozzle area ratio for jet assisted takeoff use would be:

(1) 2; (2) 5; (3) 10; (4) 25; (5) 100

28. The mass ratio of a rocket is normally defined as the weight ratio of:

(1) payload:structure; (2) propellant: total initial; (3) total initial:total final; (4) propellant:structure; (5) payload: propellant

29. The range of a ballistic vehicle on a flat earth is proportional to:

(1) burnout velocity; (2) log of mass ratio; (3) square of mass ratio; (4) square of log of mass ratio; (5) square root of burnout velocity

30. If a single-stage rocket in field-free vacuum attains a 5000 fps velocity, a two-stage combination in which the booster has the same overall characteristics as the second stage can achieve a velocity of:

(1) 7500 fps; (2) 25,000 fps; (3) 10,000 fps; (4) 15,000 fps; (5) 20,000 fps

31. The single error in injecting a satellite into its orbit which will be least likely to shorten its lifetime is:

(1) angle $\Delta\phi$ with horizontal $+5°$; (2) angle $\Delta\phi$ with horizontal $-5°$; (3) altitude Δh above ground -5 miles; (4) velocity excess $+100$ fps; (5) velocity deficiency -100 fps

32. In a missile with liquid-propellant gas generators and multiple rocket engines (which are operating at the same time), the average specific impulse is the sum of all the thrust divided by the sum of all the propellant flows which:

(1) go through the fuel pumps; (2) go through the thrust chambers; (3) go through the thrust chamber and the auxiliary power supply turbine; (4) go overboard; (5) go through the gas generator and tank pressurizing system

33. The following substance is *not* a component of a high-energy liquid rocket propellant:

(1) fluorine; (2) hydrogen; (3) hydrazine; (4) carbontetrachloride; (5) liquid oxygen

34. Which one of the following statements is *not* true? Compared to solid-propellant rockets, the liquid-propellant rockets:

(1) often have a higher specific impulse; (2) are less complex; (3) are capable of repeated starts and shutoff; (4) can usually be checked out individually before use; (5) are simple to gimbal for directional flight control

35. The principal components of a liquid-propellant rocket engine include:

(1) a thrust chamber, valves and controls; (2) an automatic burning time regulator; (3) thermal insulation against solar radiation; (4) an auxiliary power supply system; (5) none of the above

36. A case-bonded solid-propellant rocket grain is tubular in shape. Its thrust as a function of time should be described as:

(1) neutral; (2) regressive; (3) dual; (4) progressive; (5) inhibited

37. A tubular solid propellant charge is 100 in. long, has a perforation diam of 10 in., an outer diam of 30 in., and burns on all lateral surfaces and in the perforation. If the propellant burning rate is 0.5 in./sec, the rocket's burning time in seconds would be:

(1) 200; (2) 10; (3) 60; (4) 20; (5) 100

38. The chamber pressure of solid-propellant engines may be quite sensitive to area ratio, K_N, depending on the magnitude of the propellant burning rate exponent, n. At what minimum value for n will be rocket pressure rise without limit, i.e., when will combustion no longer be self regulating? (Assume a low combustion gas velocity in the charge port)

(1) ∞; (2) $-\infty$; (3) 0.0; (4) 1.0; (5) 100.0

39. A solid-propellant engine 5 in. in diam by 20 in. long is scaled to an engine 50 in. in diam. by 200 in. long. The thrust, burning time and weight of the new engine will be how many times larger, respectively, than the original engine?

(1) 100, 10, 1000; (2) 10, 100, 1000; (3) 10, 10, 100; (4) 40, 4, 160; (5) 100, 10, 100.

40. Power densities in the heat-generating-volume of useful nuclear rocket motors must be:

(1) the order of 10 kw/ft^3; (2) between 100 kw/ft^3 and 1 mw/ft^3; (3) at least the order of 100 mw/ft^3; (4) over 1000 mw/ft^3; (5) none of the above

41. Pure hydrogen is of interest for use as a nuclear rocket propellant because of its:

(1) low liquid density; (2) very low boiling point; (3) low heat of vaporization; (4) very high heat capacity (as a gas) *per unit weight;* (5) none of the above

42. In rocket reactor testing, unshielded manned operating areas (such as observation stations or test control centers) should be located:

(1) as close to the reactor test stand as possible; (2) more than 20 miles away from the test stand area; (3) close to the "hot" disassembly area; (4) at least 2 miles from the test reactor; (5) none of the above

43. The principal objection at present to the use of "gaseous"-core nuclear reactors for rocket propulsion is that:

(1) attainable gas temperatures (20,000 R and above) are too high to be useful; (2) excessive amounts of fissionable fuel will be used unless some means of fuel/propellant separation within the core can be devised; (3) the very high power required results in insoluble radiation hazard problems; (4) core gas pressures developed cannot be contained with any known materials; (5) all of the above

44. To be desirable for use in fuel elements of solid-structures heat-exchanger rocket reactors, a material should:

(1) be capable of operation above 5000 R (sufficient yield strength); (2) be a poor absorber of neutrons; (3) be resistant to corrosion by hot hydrogen; (4) be able to contain (alloy or mix with) fissionable material without appreciable loss of strength; (5) all of the above

45. A generalized design analysis is useful because it:

(1) replaces design judgment; (2) simplifies design details; (3) minimizes system interactions; (4) provides initial size and performance estimates; (5) optimizes structure

46. The technique used in formulating a generalized design analysis for a liquid propelled vehicle consists of:

(1) repeated separate analyses of each part of the vehicle; (2) interactions between a few relatively simple component analyses; (3) evaluation of conditions at launch and burnout; (4) elimination of scaling laws for various components; (5) neglect of environmental factors

47. Assuming the thickness of the wall of a liquid oxygen tank of a liquid-propellant vehicle depends on the tank pressure and allowable stress, increasing the payload:

(1) increases the thickness because pressure increases; (2) decreases the thickness because allowable stress increases; (3) changes fabrication requirements; (4) raises temperatures; (5) has unknown effect

48. A generalized dynamic analysis of a liquid-propelled vehicle does *not* give information about:

(1) fluid sloshing; (2) engine swiveling; (3) tank pressure fluctuations; (4) bending displacements; (5) control system forces

49. The presence of internal pressure in a thin walled cylindrical pressure vessel will have the following effect on the axial load-carrying ability of the cylinder:

(1) greatly increase it; (2) increase it a small amount; (3) have no effect; (4) decrease it a small amount; (5) decrease it greatly

50. The lightest liquid-propellant tank will have the following shape:

(1) cylindrical; (2) spherical; (3) will depend upon the overall missile configuration and performance; (4) will depend upon the liquid being carried; (5) some other shape will definitely be lighter

51. From a structural standpoint, staging is used:

(1) to divide the vehicle into small, easily handled parts; (2) to eliminate useless weight as flight progresses; (3) to provide joints for easy inspection and maintenance; (4) to lighten the takeoff weight; (5) none of the above

52. The current ratio of structural weight to gross takeoff weight of long range missiles and space vehicles will probably lie in the following range:

(1) 3–5%; (2) 5–10%; (3) 10–15%; (4) 15–25%; (5) 25–35%

53. Which of the following factors is *not* important in determining the distance to which effective communications can be carried out?

(1) transmitter power; (2) antenna size; (3) receiver noise figure; (4) velocity of the vehicle; (5) ability of receivers to amplify noise-free signals

54. Effective line-of-sight communications can be achieved with presently known techniques to a maximum of about:

(1) 50 miles (the ionosphere); (2) 2500 miles (artificial satellites); (3) 0.3 x 10^6 miles (moon); (4) 50 x 10^6 miles (Mars); (5) 10^{14} miles (nearest star)

55. As vehicles approach relativistic velocities, communications energy radiated omnidirectionally from the vehicle appears to a stationary observer to be:

(1) concentrated in a forward direction with respect to the vehicle's motion; (2) concentrated to the side with respect to the vehicle's motion; (3) concentrated to the rear with respect to the vehicle's motion; (4) unaffected by the vehicle's motion; (5) converted into mass

56. Extreme-distance space communications will probably use frequencies of:

(1) 0.1 to 100 kc/sec; (2) 100 to 10,000 mc/sec; (3) 10,000 to 100,000 mc/sec; (4) infrared frequency; (5) visual light frequency

57. The received power in free space radio propagation is given by:

(1) $G_T P_T R^2/4\pi A_R$; (2) $G_T P_T A_R/4\pi R^2$; (3) $4\pi G_T P_T/A_R R^2$; (4) $4\pi A_R/G_T P_T R^2$; (5) $G_T P_T A_R/(4\pi R)^2$

58. The beamwidth product $[(BW)_1 (BW)_2]$ of an antenna varies:

(1) directly as the gain; (2) inversely as the gain squared; (3) inversely as the square root of the gain; (4) directly as the gain squared; (5) inversely as the gain

59. The wavelength and frequency of a radio signal are related by:

(1) $\lambda = c/f$; (2) $\lambda = f/c$; (3) $f = \lambda/c$; (4) $\lambda = f/c^2$; (5) $\lambda^2 = f/c$

60. The diameter of the largest steerable radio telescope antenna now being built in the USA is:

(1) 10 ft; (2) 25 ft; (3) 140 ft; (4) 60 ft; (5) 500 ft

61. Which of the following statements is true for a single-degree-of-freedom, (hermetic integrating) gyroscope?

(1) the float is free to rotate relative to the case about the input axis; (2) the output signal is proportional to input angular rate; (3) the float rotates relative to the case about the output axis; (4) friction in the bearings supporting the gyro wheel is a prime cause of gyro drift; (5) the shearing force developed in the flotation fluid is of little importance in the instrument operation

62. Which of the following statements is incorrect for an accelerometer?

(1) acceleration is deduced from a measurement of force acting on a mass; (2) the accelerometer measures acceleration relative to the center of the earth; (4) friction between seismic mass and the case is an important source of error; (5) accelerometers which perform integration are useful; (6) most precision accelerometers employ a force feedback device or circuit

63. Which of the following statements is true regarding accelerometer errors in pure inertial guidance systems for flight near the surface of the earth?

(1) vertical position error increases as the square of time for a constant vertical accelerometer error; (2) vertical position errors are sinusoidal for a constant vertical accelerometer error; (3) vertical position error increases exponentially with time for a constant vertical accelerometer error; (4) horizontal position error increases as the square of time for a constant horizontal accelerometer error; (5) horizontal position error is a constant for a constant horizontal accelerometer error

64. Which of the following statements is incorrect for pure inertial guidance systems for long-range ballisticmissiles?

(1) simple airborne computation is important; (2) the guidance system provides steering signals to the control system; (3) the guidance scheme provides an implicit or explicit gravity computation; (4) steering signals are provided for the total duration of the flight; (5) initial conditions must be set into the guidance system at the start of the flight

65. If noise of power spectrum $N(\omega)$ is passed through a filter of transfer characteristic $Y(i\omega)$, the emergent noise has spectrum:

(1) $Re\,[Y(i\omega)N(\omega)]$; (2) $Y(-i\omega)N(\omega)$; (3) $|Y(i\omega)|^2 N(\omega)$; (4) $|Y(i\omega)| + N(\omega)$; (5) $|Y(i\omega)|N(\omega) + |1 - Y(i\omega)|N(-\omega)$

66. Velocity errors due to the differentiation of position data are particularly large if the position noise is:

(1) low frequency; (2) uncorrelated; (3) white; (4) high frequency; (5) stationary

67. The "weighting function" used in linear, time invariant smoothing is a function of:

(1) age of data; (2) frequency in radians per second; (3) r.m.s. error; (4) time; (5) the autocovariance

68. The terminal attraction exerted by a target planet's gravitational field reduces the nominal miss distance. This effect does *not* depend upon:

(1) target mass; (2) target radius; (3) relative velocity; (4) impact parameter; (5) absolute gravitational constant

69. All but one of the following schemes have been considered for sensing and/or controlling vehicle attitude for a satellite orbit about an alien planet:

(1) gyroscopic references; (2) horizon scanners; (3) minimum-sensing radio altimeters; (4) celestial bearings; (5) gravitational gradient torques

70. The sensitivity of impact range (ϕ) to errors in controlling the braking impulse orientation (α) was considered for descent from a circular orbit. It was found that ϕ is insensitive to $\alpha(\delta\phi/\delta\alpha = 0)$ when α is equal to:

(1) range angle (ϕ); (2) zero; (3) minimum impulse orientation; (4) angle of the resultant velocity U with respect to the local vertical (γ); (5) half the range angle ($\phi/2$)

71. Which of the following functions is not properly the responsibility of a midcourse guidance system?

(1) sensing the vehicle position and velocity; (2) controlling vehicle attitude; (3) controlling the corrective impulse(s); (4) computing the desired vehicle velocity vector; (5) supplying power to the scientific instruments aboard

72. The logarithm of the brightness of the daylight sky decreases generally in proportion to the altitude above sea level. The last perceptible traces of daylight sky brightness vanish at a height of approximately:

(1) 50,000 ft; (2) 100,000 ft; (3) 200,000 ft; (4) 500,000 ft; (5) 1,000,000 ft

73. The flux of short-wave ultraviolet radiation and of soft X-rays emitted by the sun exhibits short-term changes depending upon states of solar activity. Taking the quiet sun as normal, the intensity of these radiations during period of solar activity has been observed to increase by a factor of:

(1) 2; (2) 5; (3) 10; (4) 100; (5) 10,000

74. The safe dose for continuous exposure to ionizing radiation has been set by the AEC at 50 milliroentgen equivalent man per day (mrem/day). The cosmic ray dose received by a person at the top of the atmosphere over the geomagnetic poles would amount to:

(1) 9 mrem/day; (2) 45 mrem/day; (3) 90 mrem/day; (4) 450 mrem/day; (5) 900 mrem/day

75. During the appearance of a great solar flare in 1956, cosmic ray intensity increases were observed which decayed to normal after about one day. The radiation dose that would have been received by a crew in space outside the geomagnetic shield of the earth during these 24 hours would have been equivalent to:

(1) 130 milliroentgen; (2) 1.3 roentgen; (3) 13 roentgen; (4) 130 roentgen; (5) 1300 roentgen

76. The most practical presently available protection of the space vehicle occupants from radiation danger from high energy particles or "cosmic rays" is to provide:

(1)a shield of heavy mass; (2) a shield of hydrogen; (3) magnetic deflection fields; (4) lead plate shielding; (5) minimal shielding to reduce ionization

77. The probability of a space vehicle being struck by a meteoroid decreases sharply as:

(1) its distance from the sun increases; (2) the size of the meteoroid increases; (3) the size of the meteoroid decreases; (4) meteoroid shape varies; (5) the density of the meteoroid increases

78. The determination of maximum cabin size for a space vehicle will probably be most strongly influenced by studies in:

(1) neurology; (2) physiology; (3) biology; (4) psychology; (5) pathology

79. One of the most important ecological problems to solve for long duration space flights is that of:

(1) waste disposal; (2) oxygen re-generation; (3) providing illumination; (4) providing sleeping facilities; (5) noise abatement

80. The problem of atmospheric heating of the space vehicle surface during re-entry may be greatly mitigated by:

(1) using dry ice on the surface; (2) air-cooling the surface; (3) slowing the vehicle by retro-propulsion; (4) pointing the vehicle backwards; (5) making the surface highly reflective

81. Air in the lower atmosphere begins to be appreciably ionized at:

(1) 5000 gauss; (2) low magnetic Reynolds numbers; (3) 2000 K; (4) M = 20; (5) 4000 K

82. Magnetic field can be used as a wall or as a piston because:

(1) of the large displacement currents; (2) of the vorticity of the fluid; (3) of the interaction in the induced currents; (4) the field strength is over 5000 gauss; (5) of electrostatic repulsion

83. Nonadiabatic heating may be useful to heat deuterium to fusion reaction temperature if:

(1) the plasma boundary moves approximately 10^6 m/sec; (2) the neutrons can be contained; (3) the Bremstrahlung radiation can be maximized; (4) a magnetic nozzle can be used; (5) thermal equilibrium is maintained.

84. The characteristics of the atmosphere which least affects the accuracy of radio guidance signals is its:

(1) index of refraction; (2) degree of ionization; (3) turbulence of the ionosphere; (4) humidity; (5) chemical composition

85. The accuracy with which the relative phase of two signals must be measured to provide adequate satellite guidance is 1 part in:

(1) 10; (2) 100; (3) 5000; (4) 100,000; (5) 1,000,000

86. The Minitrack interferometers used on U.S. satellite signals at 108 mc consist of antennas spaced at 500 ft. Each antenna has a pattern in the E-W plane that is a total of 10° between nulls of the major lobe. How many interference minima will be observed as a satellite crosses the station from West to East?

(1) 2; (2) 9; (3) 10; (4) 18; (5) 20

87. A parabolic antenna is 100 ft in diam. At what wavelength does the major lobe just cover the moon—2000 miles diam at 250,000 miles distant?

(1) 1/2 ft; (2) 3 ft; (3) 30 ft; (4) 100 ft; (5) 13 ft

88. Assuming a uniform density of electrons in space between earth and moon, what density is required to give an error in range of 25 miles (1 part in 10,000) at a frequency of 100 mc?

(1) 5×10^{10}; (2) 2.5×10^{10}; (3) 2.5×10^{12}; (4) 2.5×10^{14}; (5) 5×10^{12}

89. A satellite at altitude of 200 miles in a circular orbit has a speed of approximately 5 mps. What is maximum rate of change of Doppler frequency that could be observed if transmitter of satellite is at 108 mc.?

(1) 3000 c/sec²; (2) 1500 c/sec²; (3) 7 c/sec²; (4) 73 c/sec²; (5) 15 c/sec²

90. For flight mechanical and navigational purposes, it is convenient to define regions in space. The activity sphere of a planet is defined as the circumplanetary sphere:

(1) within which the spacecraft is still subject to drag from the planet's atmosphere; (2) within which the planet perturbs the vehicle's heliocentric pass just faintly; (3) within which the planet can hold a satellite; (4) within which the planet should be regarded by an approaching or escaping spacecraft as the center body and the sun as the perturbing body, in contrast to the heliocentric flight condition; (5) within which strong planetary magnetic or electric forces affect environmental conditions, e.g., direction and intensity of corpuscular radiation

91. In the inner solar system elliptic orbits are the most important interplanetary transfer orbits. Among these, the Hohmann Ellipse is known as:

(1) the fastest ellipse which can be flown with a given ideal velocity available to the spacecraft; (2) the minimum energy transfer path between two nearly circular planet orbits; (3) the minimum energy transfer ellipse between two elliptic, noncoaxial orbits; (4) a transfer ellipse which is cotangential to one terminal orbit but not to the other; (5) the transfer ellipse which is canted with the respect to the plane of the target planet orbit

92. Transfer ellipses which intersect the target orbit are significantly more expensive than the cotangential ellipse:

(1) even when the spacecraft experiences only a hyperbolic encounter with the target planet; (2) only if very long stay times near the target planet are involved; (3) only if a two-way (round) trip is considered; (4) because the departure velocity from Earth increases rapidly even at small angles of intersection with the target orbit; (5) if capture maneuvers are involved

93. The single error in injecting a "ballistic" probe into its transfer orbit, which will cause the greatest displacement in the target planet region, is:

(CONTINUED ON PAGE 77)

I_{sp}: How high for chemical fuels?

As the search for high performance continues, attention is centered on propellants with high initial heat content per unit weight and the problem of raising the fractional conversion of this heat into thrust

By James M. Carter

CHEMALCO, INC., PASADENA, CALIF.

James M. Carter received a B.S. in chemistry from Cal Tech in 1926 and a Ph.D. in chemistry from Western Reserve in 1929. Subsequently, he spent a year as assistant to Prof. Joel Hildebrand at Berkeley and another year at the Bureau of Mines helium plant. Following 12 years in industry and work on the Manhattan Project, he went with Aerojet in 1943 and has been associated with the rocket field ever since. In 1946, he began a consulting practice, and in 1951 he opened a development laboratory, now Chemalco, Inc. In the rocket field, Dr. Carter's particular field of interest is propellants and their utilization. Co-author of two sections of the Princeton Encyclopaedia on Jet Propulsion, he has contributed numerous articles on propellants and propulsion to technical journals and holds a number of patents in the fields of chemical processing, instrumentation and rocketry.

THE IMPORTANCE of gaining high impulse with chemical propellants arises principally from the fact that such propellants require tanks, a rocket engine and auxiliary equipment for operation. The weight of this equipment constitutes a "lost payload," and sets an upper limit on the velocity increment which can be obtained with the first or any subsequent stages of a missile or space rocket. Since, to a first approximation, the ratio of this "dead" weight to propellant weight is constant for any given propellant system, the velocity increase obtainable for any stage carrying useful payloads is limited to not much more than the exhaust velocity from the rocket engine nozzle, which is simply the specific impulse times the acceleration of gravity.

A body must gain a velocity near 25,000 fps to orbit the earth as a satellite and must go over 35,000 fps to escape the earth's gravitational field. Current exhaust velocities are about 9000 fps, corresponding to a specific impulse of about 300 sec.

This means three stages for satellites, and four or more for escape, unless payloads are decreased to infinitesimal fractions of total initial weight. Increase of specific impulse to a value of 400 sec would mean that satellites of two stages would be practical, with a corresponding decrease in the number of stages for more ambitious targets. When it is realized that the useful payload, *including* total weight of any following stages, is ordinarily not over about 10 per cent of total initial weight, the importance of keeping the number of stages to a minimum is evident. Hence the importance of, and interest in, higher impulses from propellants.

Factors Affecting Performance Are Few

Basically, the problem is very simple. A rocket engine is a specialized heat engine, and there are only a few factors affecting performance. The most important of these are:

1. The maximum heat content which can be obtained per unit mass of working fluid.
2. The source of heat—internal or external.
3. The maximum fraction of the heat content which can be converted to dissected kinetic energy on expansion.
4. The limitations properties of materials impose on temperatures, pressures and other operating conditions.

5. The weight of the engine, tanks, auxiliary equipment, etc., required to utilize a given amount of propellant.

Problems involving cost of development and of production are not considered at this point.

The heat content of working fluid must always be considered together with the temperature and pressure limitations imposed by materials. Table at top right shows the heat content (H) at 3000 K of a number of gases commonly found in propellant exhaust and associated specific impulses for the usual fractions of conversion to kinetic energy.

Specific impulse increases only with the square root of heat content and fraction converted. Large increases in either are required for increases in performance. It is apparent that, in most cases, all the gases shown in the table require the admixture of hydrogen in appreciable amounts by weight to deliver a specific impulse above 300 at a temperature of 3000 K.

Heat contents at higher temperatures increase faster than the temperature, because of increases in specific heat and dissociation. Advances made in the art of cooling rocket engines and nozzles in recent years allow jumping this limitation of 3000 K to 4000 or 4500 K for chemical propellants heated by their own reaction.

Hydrogen Is a Necessity

For a working fluid heated by an external source, such as a nuclear reactor, temperatures even lower than 3000 K are excessive, and 2000 K is probably an upper limit. For a nuclear heated rocket engine, hydrogen is a necessity. The next best material, dissociated ammonia, gives a specific impulse of only 300 sec at 2000 K, while hydrogen alone will give 600 sec at 2000 K.

An external source of heat, then, does not appear practical, except when (CONTINUED ON PAGE 74)

HEAT CONTENT AND SPECIFIC IMPULSE FOR PROPELLANT GASES

Gas	Mol. wt.	H (Kcal/gm*)	I_{sp} (sec) for conversion of 50%	I_{sp} (sec) for conversion of 60%
H_2	2	11.50	707	775
He	4	3.72	401	439
H_2O	18	1.78	278	305
HF	19	1.14	222	244
CO	28	0.872	195	214
CO_2	44	0.889	197	216
N_2	28	0.866	194	213
BF_3	68	0.773	170	186

* Dissociation neglected.

HEAT OF REACTION FOR HIGH-ENERGY CHEMICAL PROPELLANTS

Compound	Heat of formation (Kcal/gm) (1)	Heat of formation (Kcal/gm) (2)
HF	3.21	—
H_2O	3.21	—
LiF	5.64	3.59
Li_2O	4.77	3. ?
BeF_2	4.83	3.86
BeO	5.84	0
MgF_2	4.23	2.96
MgO	3.57	2. ?
BF_3	3.91	—
B_2O_3	4.33	3.16
AlF_3	3.70	2.78
Al_2O_3	3.91	2.31
CO	0.94	—
CO_2	2.14	—

HIGH-ENERGY CHEMICAL BIPROPELLANTS

Propellant	Mixture ratio	Heat content (Kcal/gm)	Mat. exhaust	I_{sp} (sec)	Exhaust velocity (fps)	Per cent converted*
LOX-RP1	2.6	2.05	26.3	298.5	9,600	50.0
N_2O_4-N_2H_4	1.4	1.59	22.1	292	9,400	61.5
LOX-N_2H_4	0.9	1.88	21.7	315	10,150	66.5
F_2-N_2H_4	2.4	2.47	21.8	366	11,800	62.3
LOX-H_2	7.0	3.15	16.12	376	12,100	51.5
F_2-H_2	15.0	3.16	17.92	404	13,000	59.3

* To kinetic energy (thrust).

Cold propellants for hot performance

Cryogenic liquids show great promise in terms of high specific impulse, but considerable work lies ahead to solve storage and handling problems stemming from their toxicity and uncompromising physical characteristics

By John L. Sloop

NACA LEWIS FLIGHT PROPULSION LABORATORY, CLEVELAND, OHIO

ANYONE who has faced the problems and frustrations of handling cryogenic fluids in complex missile systems has probably longed for propellants with the properties of, say, vodka. Although vodka would make a respectable fuel, nature has failed to provide us with a potent liquid oxidizer with such nice properties—which brings us to the point immediately. Rocket engineers put up with the cryogenic propellants only for their superior performance in terms of specific impulse.

The table on page 30 summarizes performance of several well-known cryogenic propellants and, for comparison, several storable noncryogenic liquid propellants with high energy. The conditions of combustion given in the note on the table are representative of a second-stage missile or space propulsion unit. Hydrogen with ozone, fluorine and oxygen—all cryogenics—gives much higher specific impulse than the storable propellants. So, if you insist on the highest specific impulses for chemical rocket propulsion, say 400 sec or greater, then you have to look to the cryogenics.

Now let's examine some of the handling problems in store for you, as indicated on page 30. A glance at the boiling point shows that temperatures range from —168 to —423 F. This means you need refrigeration equipment and insulated tanks and lines to keep these liquids liquid for long. It can also mean external ice formation, pump cavitation and vapor formation in plumbing.

These are problems of cryogenics as a class, but there are other properties to be reckoned with. Let's consider some of these properties in terms of particular cryogenics.

John L. Sloop is chief of the Rocket Branch of NACA's Lewis Flight Propulsion Laboratory. He received a B.S. in electrical engineering from the University of Michigan in 1939. Coming to Lewis in 1941, he headed a group studying spark ignition for four years, and then for two years headed a small group working on rocket cooling. He became head of the Lewis Rocket Research Section in 1949, and that same year assumed his present position. He was recently appointed chairman of the ARS Propellants and Combustion Committee.

Oxygen—Queen of Cryogenics

Oxygen is the queen of the cryogenics, and a vast amount of experience has been acquired in its use. Air-transportable liquid oxygen generators with capacities to 1000 lb/hr are available which require only fuel and lubricating oil, and much larger stationary plants are commonplace. Oxygen, the mildest of the rocket cryogenics, is a nice oxidizer for the space traveler to have aboard, for it can also augment his breathing supply in an emergency.

Ozone can be made from oxygen by a silent electrical discharge, and is potentially cheap to make. It is very reactive and very toxic.

Theoretical Performance of High-Energy Liquid Propellants

Chamber pressure, 300 lb/sq in. abs; nozzle-exit/throat-area ratio, 25; ambient pressure, 0.

Cryogenic Fuels and Oxidizers	I_{sp} (sec)	Per cent fuel	Bulk density, (lb/cu ft)
H_2 O_2	480	17	21
H_2-F_2	463	6	43
H_2-O_2	442	15	22
Cryogenic Oxidizers Only			
N_2H_4-F_2	417	30	83
N_2H_4-OF_2	390	37	80
PRP1-O_2	342	31	63
Storable Fuels and Oxidizers			
N_2H_4-N_2O_4	330	46	75
N_2H_4-ClF_5	332	26	94
N_2H_4-H_2O_2	322	40	77

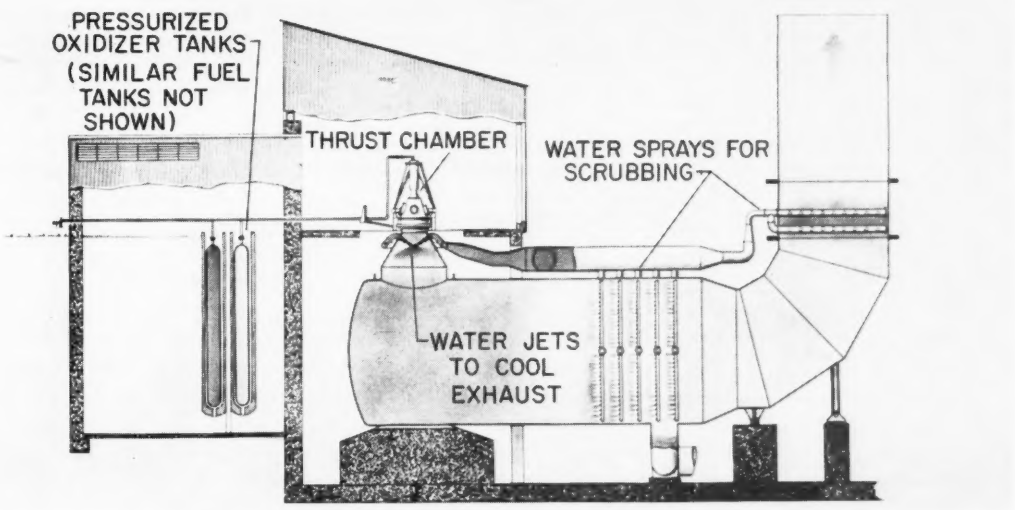
Ozone gives a higher performance with hydrogen than other oxidizers, but its superiority over fluorine comes only at the price of using a much greater proportion of hydrogen in the combustion process. The big, black cloud over ozone is its thermal instability. The literature has many particulars about its bad behavior, although researchers now attribute much of this reputation to the presence of impurities.

Ozone concentrations up to 30 per cent by weight in oxygen are considered usable, but extreme care must be taken to have contaminant-free systems and to prevent an increase in ozone concentration from oxygen boil-off. These formidable problems make ozone less attractive than fluorine at present. They also offer a great challenge to the research chemist.

Fluorine is the most promising high-energy oxidizer for immediate application. It can be used with relatively small proportions of hydrogen to give theoretical specific impulses between 450 and 500 sec. The reactivity of fluorine is well known. One never needs an igniter when this most sociable of all chemical elements meets fuel.

However, fluorine attacks most organic and inorganic substances to a certain degree. Fortunately, its attack on metals useful in missiles is slow enough

HIGH-ENERGY ROCKET TEST FACILITY


PRESSURIZED OXIDIZER TANKS (SIMILAR FUEL TANKS NOT SHOWN)
THRUST CHAMBER
WATER SPRAYS FOR SCRUBBING
WATER JETS TO COOL EXHAUST

to rate them acceptable. Aluminum, copper, brass, stainless steel, monel and nickel are satisfactory with fluorine up to room temperature and perhaps higher. Fluorine attacks these metals and forms a fluoride film, which slows further reaction. A common practice in fluorine-handling systems is to "pickle" the system, after cleaning, by using low-pressure fluorine gas to form a protective coating.

There are no suitable elastomers to use with fluorine. Teflon, the most resistant elastomer known, disappears in a stream of fluorine like sugar in water. Fluorine systems must be kept scrupulously clean of contaminants, and must have as few seals as possible, no crevices and no porous metals, metallic seals, and welds which are X-rayed to assure against cracks, slag inclusions or other impurities.

Fluorine was tagged for many years with a low specific gravity label until an alert experimenter at Aerojet-General had trouble with flowmeter calibrations and unearthed a basic error in previous measurements. Its specific gravity is 1.513 gm/cc at —188.13 C, or about 94 lb/cu ft.

Fluorine is very toxic—tenfold more so than its exhaust product, hydrogen fluoride, which can frost your glasses in a twinkling and curl your toes shortly thereafter. Fortunately, the nose is a very sensitive indicator of minute concentrations of fluorine or hydrogen fluoride, though not an infallible one. Persons with respiratory troubles are particularly vulnerable, and anyone exposed to fluorine should have periodic clinical checkups.

Fluorine Disposal Systems

There may be times in an experimental setup or at a launching site when fluorine must be disposed of. Burning with a hydrocarbon or reacting with steam have been used to dispose of small quantities. A convenient disposal system is in use at the NACA Lewis Laboratory, where fluorine and fluorine-helium mixtures are piped to insulated drums containing picnic charcoal. The fluorine reacts spontaneously with the charcoal to provide harmless carbon fluorides. Water is also a handy safety means, as it can react with fluorine to produce hydrogen fluoride, which can be absorbed by more water. Encasing fluorine systems (CONTINUED ON PAGE 96)

Properties of Cryogenic Propellants

Propellant	Boiling point (Deg F)	Critical pressure (Atm)	Critical temperature (Deg F)	Density at boiling point (lb/cu ft)	Stability	Reactivity	Acceptable materials	Toxicity for 15-min exposure
Oxygen	—297.4	49.7	—182	71.26	Very good	Nonhypergolic at ambient conditions	Nickel, monel, Inconel, copper, aluminum, stainless steel, Kel-F, teflon*	None
Fluorine	—307	55	—200.5	94.5	Very good	Hypergolic with fuels and organic compounds at low temperatures	Monel, nickel, copper, aluminium, stainless steel (300 series), brass	Extremely dangerous above 25-50 ppm, lung damage above 15–25 ppm, tolerable 0.1 ppm (continuous)
Ozone	—168	54.6	10.2	91	(0–20% O_3 in O_2) fair to good, above 20% explosive	Hypergolic with some material†	Stainless steel (302, 304, 316, 410, 416), Al (25, 35, 24S, 525, 615), Kel-F, teflon	Intolerable above 5 ppm, tolerable 0.1 ppm (continuous)
Oxygen bifluoride	—229	48.9	—72.3	95.0	Very good	Same as F_2	Same as F_2	Same as F_2
Hydrogen (normal)	—423	12.77	—400.3	4.43	Very good	Air 4.1 to 74.2 by volume, O_2 4.6 to 93.9 by volume, hypergolic with F_2	Monel, nickel, Inconel, 18-8 stainless steel, low-carbon steels	—

* Most commercial materials suitable for temperature and pressure conditions may be considered.

† Alpha-pinene, UDMH, unsaturated hydrocarbons.

Old problems for big solid rockets

While engines big enough to power even our largest ballistic missiles can be built, bringing them into being means wrestling with the solution to traditional problems, as well as the new one of transportation

By C. Dana McKinney Jr. and Loren E. Morey

ALLEGANY BALLISTICS LABORATORY, HERCULES POWDER CO., CUMBERLAND, MD.

IN PRESENT-DAY military programs, solid propellants are competing with liquids for ballistic missile applications. This makes it evident that solids can now meet the primary requirements for boosting a payload over a long and accurately predicted trajectory.

A good deal of discussion relative to the comparative merits of solids and liquids has naturally resulted, but comparisons cannot be made by considering only the primary factors—propellant specific impulse and rocket mass ratio. Other important factors, such as performance, reliability, simplicity of manufacture and maintenance, complexity of ground support equipment, safe operation, ready time and lifetime, must also be taken into consideration.

As the solid rocket industry changes its goal from the development of rocket assemblies weighing 1000 lb to that of developing rockets weighing over 10,000 lb, it is interesting to wonder whether the problems of this new era will for the most part be carryovers from former work or whether this increase in size by a factor of 10 and even larger will introduce distinctly new problems.

Only Scope of Operation Has Changed

There seem to be no problems in solid-propellant rocketry unique to the design and development of large-size units. Admittedly, the scope of operation has changed, but development agencies face the same problems they have known about for years. To discuss briefly the most important of these problems is our purpose here.

Let's begin with the shaped propellant—the grain, or charge as it is called when part of its surface is prevented from burning by an attached inhibitor. Grain design has followed two avenues: Cartridge loading and case bonding. The basic features of each are shown in the drawings on the following pages.

Cartridge loading dates back to early WW II days, when the extruded cylinders of colloided nitrocellulose used in guns were adapted for use in the bazooka and barrange rocket. Case-bonded design began late in the war with the use of rockets to provide takeoff assistance for aircraft.

McKinney Morey

C. Dana McKinney Jr., is director of research at Allegany Ballistics Lab, a government-owned facility operated by Hercules Powder Co. under contract to Navy BuOrd, and has been connected with that facility since 1955. Prior to that date, he was a research supervisor at the Hercules Research Center near Wilmington, Del., engaged in various research projects on commercial and military explosives. Dr. McKinney was awarded a B.S. degree by the University of Chattanooga and a Ph.D. by the Illinois Institute of Technology. He is a member of the Solid Rocket Technical Committee of ARS.

Loren E. Morey entered rocket research during WW II at Allegany Ballistics Lab, when the installation was under the direction of George Washington Univ. After the end of hostilities, he worked at Midwest Research Institute and the Univ. of Kansas City before returning to the laboratory in 1950. He is now group supervisor in ballistics research. Dr. Morey received his B.S. degree from Monmouth College and his graduate degree from Columbia Univ.

Today, both cartridge-loaded and case-bonded propellant charges of appreciable size are produced by casting, with extrusion techniques used mostly for small rockets. Propellant ingredients are poured directly into the rocket case, or shell, and the mass turns into a solid charge by polymerization or plasticizer action.

From the standpoint of producing high-performance rockets, the cartridge-loaded system has several disadvantages. It requires sufficient clearance between the inside diameter of the rocket chamber and the outside diameter of the propellant grain for inserting the charge. In a high-performance unit, this wasted space is intolerable. The cartridge-loaded unit, moreover, needs a relatively thick layer of noncombustible plastic on the outside peripheral surface of the grain to prevent burning on the propellant surface next to the rocket shell. This inhibitor not only takes up space but adds to the inert weight of the assembly.

The cartridge-loaded charge also requires extra chamber insulation, a trap to prevent expulsion of the charge, or part of it, before the propellant is consumed, and full-diameter end connections to the shell to allow insertion of the cartridge charge. These all add inert weight to the rocket.

It is clear that high-performance solid rockets require a case-bonded design. The wasted space for loading clearance and inhibitor, as well as the inert weight of the inhibitor, trapping and shell insulation, cannot be tolerated.

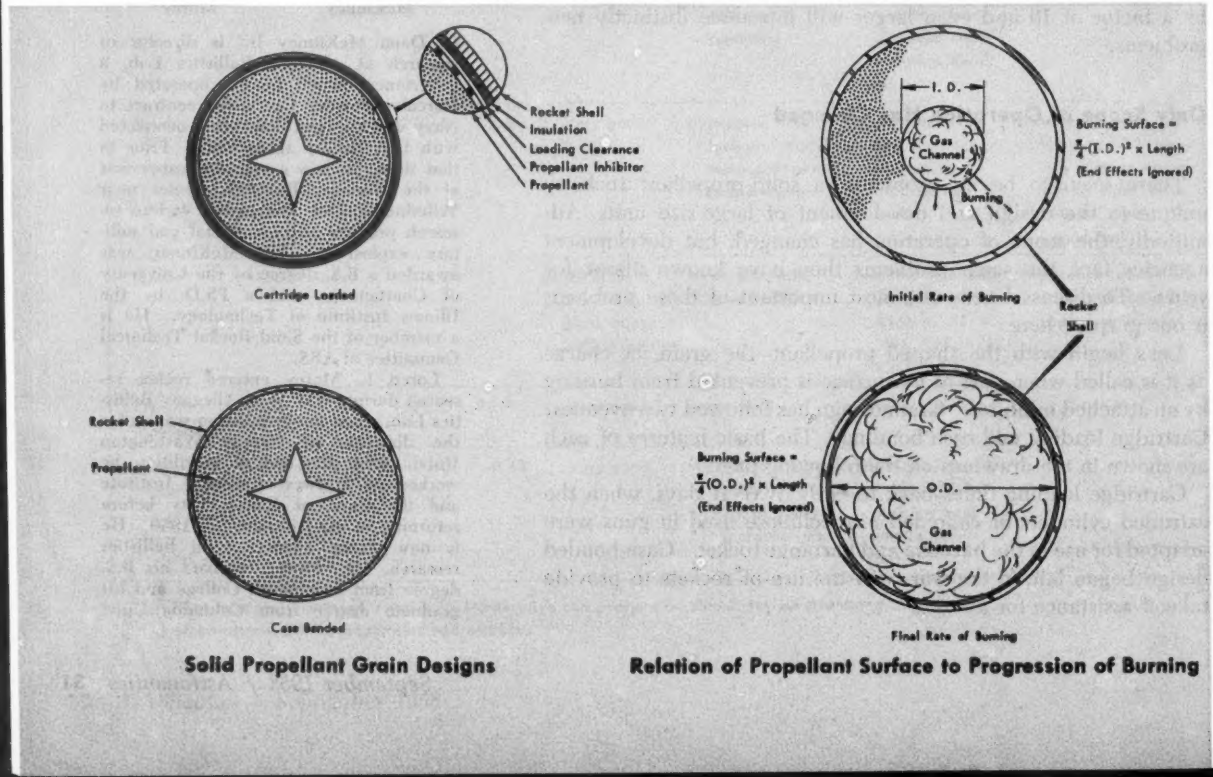
On the other hand, the manufacture of cartridge-loaded charges need not be delayed by the lack of inert parts. Charges can be manufactured and stored until inert parts are available. The rocket can then be loaded and made ready to fire in a very short time after receipt of such parts. Furthermore, cartridge charges are easier to inspect for some defects than a charge bonded into the motor case.

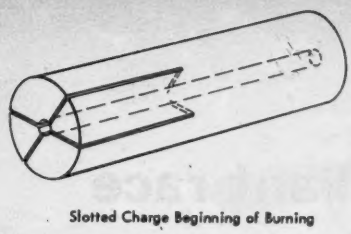
The major disadvantage of case-bonded units, however, is that the propellant must stretch as the chamber stretches when subjected to operating pressure. The problem lies in finding a propellant which has sufficient extensibility at low temperature but does not become too extensible at high temperature.

Depends on Propellant Geometry

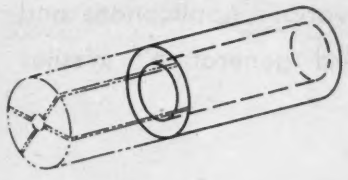
Let's turn now to the shape of the grain. The performance of a solid rocket is dependent on the geometry of the propellant. The grain burns in a direction normal to all of the exposed (uninhibited) surface. A propellant charge which burns only on an internal perforation is preferred because the pressure shell is protected from the hot gas by the remaining propellant, and the shell can thus be made much lighter than it can if subjected to a flow of hot gases.

The drawings on this page show initial and final peripheries of a simplified propellant grain with a round perforation. The grain surface will increase during burning by a factor equal to the square of the ratio of the inside diameter of the chamber to the inside diameter of the gas channel, or port (end effects ignored). This progression of the burning surface is almost always unacceptable. The initial



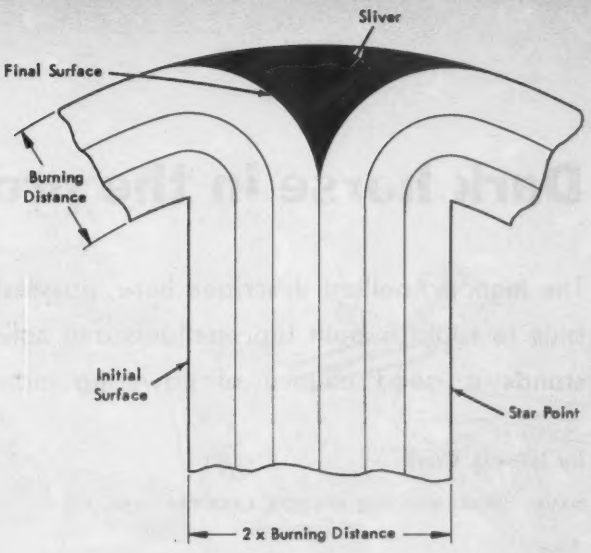


Slotted Charge Beginning of Burning



Slotted Charge Near End of Burning

Compensation of Final Surface by Slotted Charge



Sliver Pattern

surface is commonly increased by the addition of star points or slots to give more neutral burning.

The thrust (F) of a rocket is given by the equation, $F = \dot{m}\, I_{sp} = P\, SrI_{sp}$, where $\dot{m}$ is the mass flow, I_{sp} the specific impulse, p the propellant density, S the propellant burning surface, and r the propellant burning rate. Missile designers usually require acceleration to be nearly constant throughout the burning phase. Since the mass of the rocket decreases during flight, a regressive thrust-time characteristic is called for, and the surface of the propellant grain must be greater at the beginning than at the end of burning. This is just the opposite of what would be given by an internally burning grain with a simple cylindrical perforation.

One out for the rocket designer lies in the slotted charge, an example of which is shown on this page. The slotted section is designed so that, at the end of burning, this section of the grain has vanished entirely and the final surface of the propellant is considerably less than the internal surface of the grain as it was at first.

At some time before the end of burning of the slotted charge, the chamber wall will be subjected to heating. It must therefore be insulated, which adds to the inert weight of the assembly.

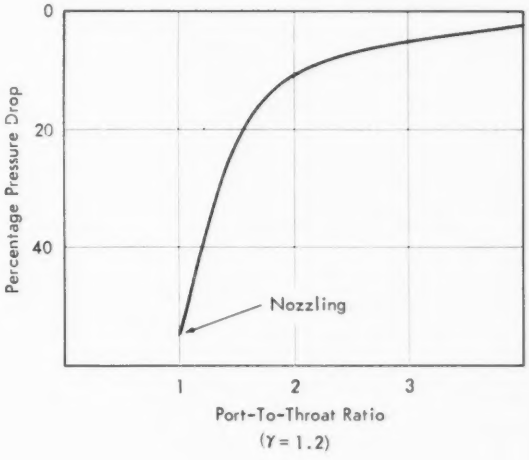
The initial and final burning surfaces are usually balanced by making the central perforation of the grain in the form of a star or some similar shape, such as a cross. This complication of propellant grain design leads to slivers, illustrated on this page. The amount of sliver depends on burning rate, burning time and other characteristics. A charge with 5 per cent of the propellant doing nothing but adding to the inert weight of the assembly is not uncommon.

The specific impulse (I_{sp}) of the propellant is related to the chemical reaction of the propellant ingredients by the equation,

$$I_{sp} = \sqrt{2\,\frac{J}{g}\,(h_c - h_e)} = \sqrt{\frac{2J\Delta H}{gM}}$$

where h_c is the specific enthalpy of the propellant gases within the rocket chamber, h_e is the specific enthalpy of the rocket gases after they have been discharged from the rocket nozzle, J is the mechanical equivalent of heat, ΔH is the molar heat of combustion, and M is the average molecular weight of the gases. From this (CONTINUED ON PAGE 92)

Pressure Drop in a Rocket as a Function Of Grain Port to Nozzle Throat Area Ratio



Dark horse in the propellant race

The monopropellant described here, possessing many favorable properties, bids to replace both bipropellants and solids in various applications and stands a good chance of powering many "third generation" missiles

By John D. Clark

NAVAL AIR ROCKET TEST STATION, LAKE DENMARK, N.J.

John D. Clark is head of the Propellants Division of the U.S. Naval Air Rocket Test Station. A physical chemist, he received his B.S. at the California Institute of Technology, his M.S. at the University of Wisconsin, and his Ph.D. at Stanford University in 1934. He worked for GE, John Wyeth and Brothers, and Wallace-Tiernan before joining NARTS, then just starting as the Naval Aeronautical Rocket Laboratory, in November, 1949. He founded the chemistry branch there in 1950, and assumed his present position in January, 1956. His major professional work for the past four years has been directed toward the development of usable high-energy monopropellants. The opinions expressed in this article are the author's and do not necessarily reflect those of the Navy Department.

MONOPROPELLANTS have long been stepchildren—the Cinderellas of the propellant family. For years the bipropellant liquid systems held the center of the stage, and now the solids, particularly those found more easily in a salesman's notebook than in a rocket, are elbowing their way into the spotlight, loudly proclaiming their ability to do everything that the liquids can do, only better.

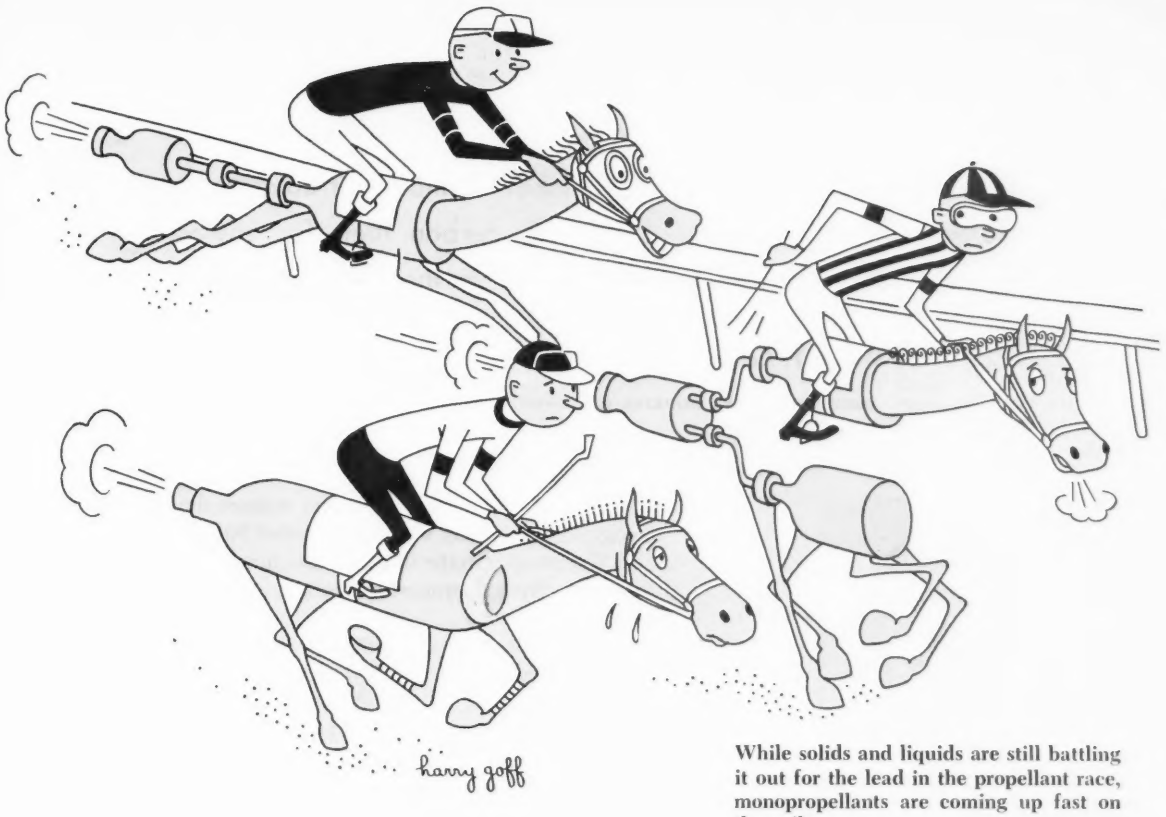
In the meantime, liquid monopropellants have been pointedly ignored. In the minds of most rocket engineers and, in actual fact, until quite recently, there were just two sorts of monopropellants. The first were low-energy compounds like ethylene oxide—all right for running an auxiliary propulsion unit, but certainly without the performance needed for primary propulsion. The other group, with energy comparable to some of the bipropellant systems, consisted solely of touchy and violently explosive liquids with a strong family resemblance to nitroglycerine. Definitely nothing to use in a rocket!

Candidates Came in Two Families

The candidates for the title of high-energy monopropellant came in two families. The first consisted of pure chemical compounds, such as methyl nitrate (CH_3NO_3), a molecule with a reducing end and an oxidizing end, separated by a pair of firmly crossed fingers. The second family consisted of solutions of a fuel in an oxidizer, such as benzene in nitrogen tetroxide. These latter would have been very useful as high explosives if there had been any method of handling them without getting yourself blown up. "High-energy" monopropellants, with very good reason, were a byword and a hissing.

But they no longer need be. A new type of monopropellant, under development at the Naval Air Rocket Test Station for the last four years, possesses such favorable properties that it may well take the place of both bipropellants and solids in many applications, and appears likely to power many of the "third generation" of missiles.

This propellant has been made and handled with perfect safety, and it has been fired not once but scores of times. Its nature and composition must unfortunately remain classified, because, once the general idea is known, the synthesis of the propellant and the possibilities of the system are as obvious as a ham sandwich.



While solids and liquids are still battling it out for the lead in the propellant race, monopropellants are coming up fast on the rail.

Since the curse of previous high-energy monopropellants was the danger attending use, the safety angle should be considered first. The new monopropellant is apparently immune to ordinary mechanical shock. A bottle of the material has been dropped 30 ft onto concrete, and all that happened was that the bottle smashed. It appears to be completely immune to adiabatic compression—unlike such propellants as n. propyl nitrate.

It *can* be exploded by gunfire or by a sufficiently violent explosive shock—as can, for that matter, solid propellants—but no conceivable maltreatment in shipping or handling seems to bother it. From this point of view, it is no harder to live with than are double-base solids.

The new monopropellant is safe in storage at any temperature that will be encountered, and it is not subject to catalytic decomposition. It is not a fire hazard—it will not even burn at atmospheric pressure—and what fumes it gives off are much less troublesome than those of other systems.

Since the primary business of a propellant is to propel, performance is the next thing to consider. This type of monopropellant has a measured specific impulse well above 200 sec (at 300/14.7 psia) with a low characteristic chamber length (L^*) and extremely simple injector. One very successful injector consisted of six commercial oil-burner spray nozzles, which cost 79 cents each.

Performance Makes It Competitive

This performance, together with the monopropellant's high density, makes it competitive not only with the solids but with the workhorse bipropellants as well. It can be used for regenerative cooling.

Moreover, its freezing and boiling points are no problem, easily meeting military specifications. Nor is there any difficulty in long-term storage. Corrosion and pressure build-up are negligible in stainless steel or aluminum containers, and prepackaging is easy.

Logistically, the material is very attractive. The raw materials are cheap and abundant, and they can be utilized *with existing and standard equipment*, by any chemical process plant above the level of a garage hobbyshop.

Let's look at the advan- (CONTINUED ON PAGE 86)

Ramjet fuels: A brief survey

Common petroleum derivatives offer a number of important advantages at the moment, but the virtues of nonhydrocarbon fuels for special applications present sufficient justification for further intensive study

By Walter G. Berl and Waldo T. Renich

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Walter G. Berl is a member of the principal staff of the Johns Hopkins Applied Physics Laboratory. He received his Ph.D. in physical chemistry at the Carnegie Institute of Technology in 1942, joining APL three years later. At the Laboratory, he has worked on the development of powerplants for supersonic aircraft, as well as on fuels and combustion. He was a member of the NACA subcommittee on combustion from 1947 to 1949.

Waldo T. Renich is an associate mathematician at the Applied Physics Laboratory of Johns Hopkins. His work includes analysis of fuel combustion problems and programming high-speed digital computers to determine performance parameters of ramjet fuels. He received his B.A. in chemistry from Bethel College, and did graduate work in chemistry and mathematics at the University of Kansas before joining APL in 1955.

A SATISFACTORY fuel for ramjet engines should offer a good compromise among such often-stated but frequently irreconcilable factors as specific impulse, kinetics of combustion, safety and health, physical properties, storage and handling, and availability and cost.

In view of the current debate over solid fuels, "exotic" fuels, slurried and gelatinized metals, etc., let's take a look at some potential ramjet fuels in the light of these factors.

For survey purposes, let's use a typical air-breathing supersonic ramjet, and assume that only the oxygen in the air serves as an oxidizer and that solid, liquid or gaseous fuels can be burned in the engine. How can promising fuels be weeded systematically from among the many elements and compounds that qualify by combining with oxygen to produce heat and work?

Consider first the theoretical heat release of a fuel—its thermochemical potential. The energy which becomes available as heat when any element or compound combines with oxygen has an upper limit of approximately 160 kcal for every new oxygen bond formed. Much less energy than this is released in the formation of nonionic bonds (e.g., CO_2) or bonds of mixed character (e.g., SiO_2).

Lightest Elements Warrant Consideration

Heat release, then, is a function of the number and the strength of the oxygen bonds formed in the production of one mole of oxide. A heavy element liberates no more energy per oxygen bond than does a lighter element. A heavy element or compound containing it will therefore produce less heat than an equal *weight* of a lighter element or related compound. Thus we find only the lightest elements and related compounds warranting serious thermochemical consideration.

Now let's look at a measure of thermodynamic efficiency—specific impulse. We can define two terms. The first is air specific impulse (S_a), which represents thrust available from a complete heat release of fuel per unit weight of air taken into the ramjet. The value of the air specific impulse is set by the density change in the working fluid brought about by the heat addition and

PHYSICAL CONSTANTS OF POTENTIAL RAMJET FUELS

Fuel	Melting point, C	Boiling point, C	Density*	Stoichiometric air/fuel ratio	Net heat of combustion (Kcal/gm fuel)	Net heat of combustion (Kcal/cc fuel)	Net heat of combustion (Kcal/gm air)
Hydrogen	−259	−253	0.07	34.29	28.67	2.01	0.84
Lithium	180	1326	0.53	4.98	10.26	5.44	2.06
Beryllium	1283	2475	1.85	7.67	16.20	29.97	2.11
Boron	2040	3925	2.45	9.58	13.91	34.08	1.45
Carbon	†	4347	2.25	11.51	7.83	17.62	0.68
Sodium	98	889	0.97	1.50	2.16	2.10	1.44
Magnesium	650	1120	1.74	2.84	5.91	10.28	2.08
Aluminum	660	2327	2.70	3.84	7.40	19.98	1.93
Silicon	1410	2675	2.4	4.92	7.21	17.30	1.47
Calcium	850	1490	1.54	1.72	3.79	5.84	2.20
Lithium hydride, LiH	680	—	0.82	8.70	9.88	8.10	1.14
Diborane, B_2H_6	−165.5	−92.5	0.45	14.98	17.3	7.79	1.15
Pentaborane, B_5H_9	−46.9	58	0.62	13.13	16.2	10.04	1.23
Decaborane, $B_{10}H_{14}$	99.5	213	0.94	12.43	15.7	14.76	1.26
Octane, C_8H_{18}	−56.8	125.7	0.70	15.13	10.62	7.43	0.70
Decene, $C_{10}H_{20}$	−66.3	170.6	0.74	14.79	10.54	7.80	0.71
Acetylene, C_2H_2	†	−84.0	0.62	13.27	11.53	7.15	0.87
Ethylene oxide, C_2H_4O	−112.5	10.6	0.89	7.85	6.62	5.89	0.84
Propylene oxide, C_3H_6O	—	35	0.83	9.52	7.37	6.12	0.77
Silicon hydride, SiH_4	−185	−111	0.68	8.61	9.44	6.42	1.10
Cyanogen, C_2N_2	−28	−21	0.87	5.31	5.03	4.38	0.95

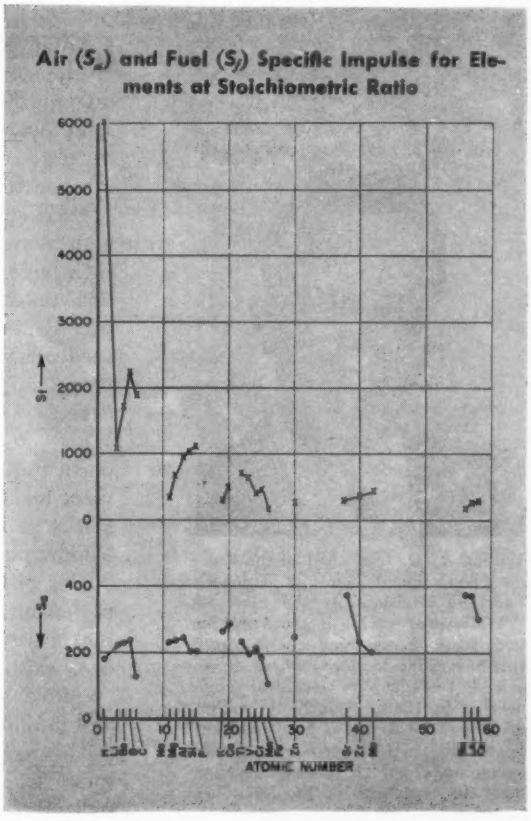
* Liquids and solids. † Sublimes.

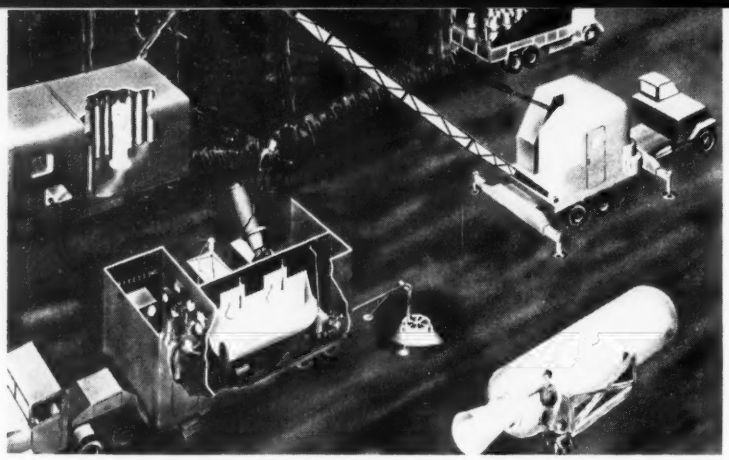
chemical changes during combustion. The second term is fuel specific impulse (S_f), which represents thrust available per unit weight of fuel and specifies how much fuel is required to produce a desired density change.

The graph at right gives plots of S_a and S_f for stoichiometric mixtures of many elements burning in air. A correlation appears between atomic number and specific impulse; S_a increases somewhat but S_f drops rapidly as we go up the periodic table. Values of S_f peak at boron, and hydrogen takes an exceptionally high position. Beryllium and carbon show nearly the same impulses, although carbon drops considerably in S_a. Hydrogen, unattractive alone because of its undesirable storage properties (especially its very low liquid density), can nevertheless be exploited if bound chemically in hydrocarbons.

Among hydrocarbons, the best performance will be obtained from compounds with large hydrogen-carbon ratios (saturated paraffins) or with strongly negative heats of formation (acetylene). A similar argument holds for hydrogen derivatives of boron and beryllium. Magnesium and aluminum, although noticeably inferior in S_f to light elements, can give adequate S_a but at the price of a high rate of fuel consumption.

These brief examinations of the thermodynamic potential of fuels indicate (CONTINUED ON PAGE 68)





Mobile loading plant. Control van and blender unit (left foreground) feeds propellant to engine in underground site. Other important elements would be a power supply (left rear) and a derrick, used to move propellant fractions in tanks from trucks in which they would be delivered to the site, to the blender.

A solid proposal

Here's how as much as 125 tons of solid propellant could be mixed and cast at the launching site to provide power for large rocket vehicles

By William F. Haite

REDSTONE DIV., THIOKOL CHEMICAL CORP., HUNTSVILLE, ALA.

William F. Haite is chief of the Process Development Dept. at Thiokol's Redstone Division. At the close of WW II, after serving in the Army for two years, he entered the Georgia Institute of Technology, where he received a degree in chemical engineering in 1949. Shortly thereafter, he joined the Redstone Div., and has been with Thiokol ever since. Before becoming chief of process development, he was head of the Division's chemical engineering section.

LARGE SPACE ships and satellites will have to be lifted from the earth's surface by first-stage rockets with very high thrust—say anywhere from half million pounds to ten times that much. A solid rocket engine with as much as 125 tons of propellant has been suggested for this job. This engine, as a first stage, would be part of a rocket several hundred feet high.

Excellent results in static firings of several solid rocket engines with more than 5 tons of propellant each lead us to believe that such huge engines are possible. We would not expect "auto-ignition" on casting the propellant for huge engines, nor would we expect ignition problems. Specific impulse of the propellant to be used would be greater than 200 sec. In other words, 125 tons of the propellant would give a total impulse greater than 50 million lb-sec.

Since the size of the rocket we are talking about makes transporting it impossible for practical purposes with existing equipment and thoroughfares, we propose instead to build at least the first stage at the launching site with the aid of a mobile propellant-loading plant like the one illustrated at the top of this page.

This plant would blend premixed fractions of a paste or slurried propellant and continuously cast the blend into a previously built rocket case. Premixed fractions would be taken by rail or truck from existing plants throughout the country to the loading site in "positive discharging" containers. Blending de-aerating, curing and finishing would be handled by the mobile plant.

The rocket case, fabricated in much the same manner as large tanks, would be erected at the launching site to receive the propellant. Lesser parts of the rocket, such (CONTINUED ON PAGE 53)

The NASA act—"A historic step"

Complete text of the act creating our first civilian space agency, pledged to peaceful projects that will be of benefit to all mankind

✦

H. R. 12575—National Aeronautics and Space Act

Eighty-fifth Congress of the United States of America

AT THE SECOND SESSION

Begun and held at the City of Washington on Tuesday, the seventh day of January, one thousand nine hundred and fifty-eight

AN ACT

TO PROVIDE FOR RESEARCH INTO PROBLEMS OF FLIGHT WITHIN AND OUTSIDE THE EARTH'S ATMOSPHERE, AND FOR OTHER PURPOSES

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

TITLE I—SHORT TITLE, DECLARATION OF POLICY, AND DEFINITIONS

SEC. 101. This Act may be cited as the "National Aeronautics and Space Act of 1958".

Declaration of Policy and Purpose

SEC. 102. (a) The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind.

(b) The Congress declares that the general welfare and security of the United States require that adequate provision be made for aeronautical and space activities. The Congress further declares that such activities shall be the responsibility of, and shall be directed by, a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except that activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the responsibility of, and shall be directed by, the Department of Defense; and that determination as to which such agency has responsibility for and direction of any such activity shall be made by the President in conformity with section 201 (e).

(c) The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

(1) The expansion of human knowledge of phenomena in the atmosphere and space;

(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;

(3) The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;

(4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;

(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;

(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;

(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof; and

(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment.

(d) It is the purpose of this Act to carry out and effectuate the policies declared in subsections (a), (b), and (c).

Definitions

SEC. 103. As used in this Act—

(1) the term "aeronautical and space activities" means (A) research into, and the solution of, problems of flight within and outside the earth's atmosphere, (B) the development, construction, testing, and operation for research purposes of aeronautical and space vehicles, and (C) such other activities as may be required for the exploration of space; and

(2) the term "aeronautical and space vehicles" means aircraft, missiles, satellites, and other space vehicles, manned and unmanned, together with related equipment, devices, components, and parts.

TITLE II—COORDINATION OF AERONAUTICAL AND SPACE ACTIVITIES

National Aeronautics and Space Council

SEC. 201. (a) There is hereby established the National Aeronautics and Space Council (hereinafter called the "Council") which shall be composed of—

(1) the President (who shall preside over meetings of the Council);

(2) the Secretary of State;

(3) the Secretary of Defense;

(4) the Administrator of the National Aeronautics and Space Administration;

(5) the Chairman of the Atomic Energy Commission;

(6) not more than one additional member appointed by the President from the departments and agencies of the Federal Government; and

(7) not more than three other members appointed by the President, solely on the basis of established records of distinguished achievement, from among individuals in private life who are eminent in science, engineering, technology, education, administration, or public affairs.

President's Statement on Space Agency

Full text of President Eisenhower's statement on signing of the NASA Act, July 29, 1958:

I have today signed H.R. 12575, the National Aeronautics and Space Act of 1958.

The enactment of this legislation is a historic step, further equipping the United States for leadership in the space age. I wish to commend the Congress for the promptness with which it has created the organization and provided the authority needed for an effective national effort in the fields of aeronautics and space exploration.

The new act contains one provision that requires comment. Section 205 authorizes cooperation with other nations and groups of nations in work done pursuant to the act in the peaceful application of the results of such work, pursuant to international agreements entered into by the President with the advice and consent of the Senate. I regard this section merely as recognizing that international treaties may be made in this field, and as not precluding, in appropriate cases, less formal arrangements for cooperation. To construe the section otherwise would raise substantial constitutional questions.

The present National Advisory Committee for Aeronautics, with its large and competent staff and well-equipped laboratories, will provide the nucleus of the NASA. The NACA has an established record of research performance and of cooperation with the armed services. The combination of space exploration responsibilities with the NACA's traditional aeronautical research functions is a natural evolution.

The enactment of the law establishing the NACA in 1915 proved a decisive step in the advancement of our civil and military aviation. The Aeronautics and Space Act of 1958 should have an even greater impact on our future.

(b) Each member of the Council from a department or agency of the Federal Government may designate another officer of his department or agency to serve on the Council as his alternate in his unavoidable absence.

(c) Each member of the Council appointed or designated under paragraphs (6) and (7) of subsection (a), and each alternate member designated under subsection (b), shall be appointed or designated to serve as such by and with the advice and consent of the Senate, unless at the time of such appointment or designation he holds an office in the Federal Government to which he was appointed by and with the advice and consent of the Senate.

(d) It shall be the function of the Council to advise the President with respect to the performance of the duties prescribed in subsection (e) of this section.

(e) In conformity with the provisions of section 102 of this Act, it shall be the duty of the President to—

(1) survey all significant aeronautical and space activities, including the policies, plans, programs, and accomplishments of all agencies of the United States engaged in such activities;

(2) develop a comprehensive program of aeronautical and space activities to be conducted by agencies of the United States;

(3) designate and fix responsibility for the direction of major aeronautical and space activities;

(4) provide for effective cooperation between the National Aeronautics and Space Administration and the Department of Defense in all such activities, and specify which of such activities may be carried on concurrently by both such agencies notwithstanding the assignment of primary responsibility therefor to one or the other of such agencies; and

(5) resolve differences arising among departments and agencies of the United States with respect to aeronautical and space activities under this Act, including differences as to whether a particular project is an aeronautical and space activity.

(f) The Council may employ a staff to be headed by a civilian executive secretary who shall be appointed by the President by and with the advice and consent of the Senate and shall receive compensation at the rate of $20,000 a year. The executive secretary, subject to the direction of the Council, is authorized to appoint and fix the compensation of such personnel, including not more than three persons who may be appointed without regard to the civil service laws or the Classification Act of 1949 and compensated at the rate of not more than $19,000 a year, as may be necessary to perform such duties as may be prescribed by the Council in connection with the performance of its functions. Each appointment under this subsection shall be subject to the same security requirements as those established for personnel of the National Aeronautics and Space Administration appointed under section 203 (b) (2) of this Act.

(g) Members of the Council appointed from private life under subsection (a) (7) may be compensated at a rate not to exceed $100 per diem, and may be paid travel expenses and per diem in lieu of subsistence in accordance with the provisions of section 5 of the Administrative Expenses Act of 1946 (5 U. S. C. 73b-2) relating to persons serving without compensation.

National Aeronautics and Space Administration

SEC. 202. (a) There is hereby established the National Aeronautics and Space Administration (hereinafter called the "Administration"). The Administration shall be headed by an Administrator, who shall be appointed from civilian life by the President by and with the advice and consent of the Senate, and shall receive compensation at the rate of $22,500 per annum. Under the supervision and direction of the President, the Administrator shall be responsible for the exercise of all powers and the discharge of all duties of the Administration, and shall have authority and control over all personnel and activities thereof.

(b) There shall be in the Administration a Deputy Administrator, who shall be appointed from civilian life by the President by and with the advice and consent of the Senate, shall receive compensation at the rate of $21,500 per annum, and shall perform such duties and exercise such powers as the Administrator may prescribe. The Deputy Administrator shall act for, and exercise the powers of, the Administrator during his absence or disability.

(c) The Administrator and the Deputy Administrator shall not engage in any other business, vocation, or employment while serving as such.

Functions of the Administration

SEC. 203. (a) The Administration, in order to carry out the purpose of this Act, shall—

(1) plan, direct, and conduct aeronautical and space activities;

(2) arrange for participation by the

scientific community in planning scientific measurements and observations to be made through use of aeronautical and space vehicles, and conduct or arrange for the conduct of such measurements and observations; and

(3) provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof.

(b) In the performance of its functions the Administration is authorized—

(1) to make, promulgate, issue, rescind, and amend rules and regulations governing the manner of its operations and the exercise of the powers vested in it by law;

(2) to appoint and fix the compensation of such officers and employees as may be necessary to carry out such functions. Such officers and employees shall be appointed in accordance with the civil-service laws and their compensation fixed in accordance with the Classification Act of 1949, except that (A) to the extent the Administrator deems such action necessary to the discharge of his responsibilities, he may appoint and fix the compensation (up to a limit of $19,000 a year, or up to a limit of $21,000 a year for a maximum of ten positions) of not more than two hundred and sixty of the scientific, engineering, and administrative personnel of the Administration without regard to such laws, and (B) to the extent the Administrator deems such action necessary to recruit specially qualified scientific and engineering talent, he may establish the entrance grade for scientific and engineering personnel without previous service in the Federal Government at a level up to two grades higher than the grade provided for such personnel under the General Schedule established by the Classification Act of 1949, and fix their compensation accordingly;

(3) to acquire (by purchase, lease, condemnation, or otherwise), construct, improve, repair, operate, and maintain laboratories, research and testing sites and facilities, aeronautical and space vehicles, quarters and related accommodations for employees and dependents of employees of the Administration, and such other real and personal property (including patents), or any interest therein, as the Administration deems necessary within and outside the continental United States; to lease to others such real and personal property; to sell and otherwise dispose of real and personal property (including patents and rights thereunder) in accordance with the provisions of the Federal Property and Administrative Service Act of 1949, as amended (40 U. S. C. 471 et seq.); and to provide by contract or otherwise for cafeterias and other necessary facilities for the welfare of employees of the Administration at its installations and purchase and maintain equipment therefor;

(4) to accept unconditional gifts or donations of services, money, or property, real, personal, or mixed, tangible or intangible;

(5) without regard to section 3648 of the Revised Statutes, as amended (31 U. S. C. 529), to enter into and perform such contracts, leases, cooperative agreements, or other transactions as may be necessary in the conduct of its work and on such terms as it may deem appropriate, with any agency or instrumentality of the United States, or with any State, Territory, or possession, or with any political subdivision thereof, or with any person, firm, association, corporation, or educational institution. To the maximum extent practicable and consistent with the accomplishment of the purpose of this Act, such contracts, leases, agreements, and other transactions shall be allocated by the Administrator in a manner which will enable small-business concerns to participate equitably and proportionately in the conduct of the work of the Administration;

(6) to use, with their consent, the services, equipment, personnel, and facilities of Federal and other agencies with or without reimbursement, and on a similar basis to cooperate with other public and private agencies and instrumentalities in the use of services, equipment, and facilities. Each department and agency of the Federal Government shall cooperate fully with the Administration in making its services, equipment, personnel, and facilities available to the Administration, and any such department or agency is authorized, notwithstanding any other provision of law, to transfer to or to receive from the Administration, without reimbursement, aeronautical and space vehicles, and supplies and equipment other than administrative supplies or equipment;

(7) to appoint such advisory committees as may be appropriate for purposes of consultation and advice to the Administration in the performance of its functions;

(8) to establish within the Administration such offices and procedures as may be appropriate to provide for the greatest possible coordination of its activities under this Act with related scientific and other activities being carried on by other public and private agencies and organizations;

(9) to obtain services as authorized by section 15 of the Act of August 2, 1946 (5 U. S. C. 55a), at rates not to exceed $100 per diem for individuals;

(10) when determined by the Administrator to be necessary, and subject to such security investigations as he may determine to be appropriate, to employ aliens without regard to statutory provisions prohibiting payment of compensation to aliens;

(11) to employ retired commissioned officers of the armed forces of the United States and compensate them at the rate established for the positions occupied by them within the Administration, subject only to the limitations in pay set forth in section 212 of the Act of June 30, 1932, as amended (5 U. S. C. 59a);

(12) with the approval of the President, to enter into cooperative agreements under which members of the Army, Navy, Air Force, and Marine Corps may be detailed by the appropriate Secretary for services in the performance of functions under this Act to the same extent as that to which they might be lawfully assigned in the Department of Defense; and

(13) (A) to consider, ascertain, adjust, determine, settle, and pay, on behalf of the United States, in full satisfaction thereof, any claim for $5,000 or less against the United States for bodily injury, death, or damage to or loss of real or personal property resulting from the conduct of the Administration's functions as specified in subsection (a) of this section, where such claim is presented to the Administration in writing within two years after the accident or incident out of which the claim arises; and

(B) if the Administration considers that a claim in excess of $5,000 is meritorious and would otherwise be covered by this paragraph, to report the facts and circumstances thereof to the Congress for its consideration.

Civilian-Military Liaison Committee

SEC. 204. (a) There shall be a Civilian-Military Liaison Committee consisting of—

(1) a Chairman, who shall be the head thereof and who shall be appointed by the President, shall serve at the pleasure of the President, and shall receive compensation (in the manner provided in subsection (d)) at the rate of $20,000 per annum;

(2) one or more representatives from the Department of Defense, and one or more representatives from each of the Departments of the Army, Navy, and Air Force to be assigned by the Secretary of Defense to serve on the Committee without additional compensation; and

(3) representatives from the Administration, to be assigned by the Administrator to serve on the Committee without additional compensation, equal in number to the number of representatives assigned to serve on the Committee under paragraph (2).

(b) The Administration and the Department of Defense, through the Liaison Committee, shall advise and consult with each other on all matters within their respective jurisdictions relating to aeronautical and space activities and shall keep each other fully and currently informed with respect to such activities.

(c) If the Secretary of Defense concludes that any request, action, proposed action, or failure to act on the part of the Administrator is adverse to the responsibilities of the Department of Defense, or the Administrator concludes that any request, action, proposed action, or failure to act on the part of the Department of Defense is adverse to the responsibilities of the Administration, and the Administrator and the Secretary of Defense are unable to reach an agreement with respect thereto, either the Administrator or the Secretary of Defense may refer the matter to the President for his decision (which shall be final) as provided in section 201 (e).

(d) Notwithstanding the provision of any other law, any active or retired officer of the Army, Navy, or Air Force may serve as Chairman of the Liaison Committee without prejudice to his active or retired status as such officer. The compensation received by any such officer for his service as Chairman of the Liaison Committee shall be equal to the amount (if any) by which the compensation fixed by subsection (a) (1) for such Chairman exceeds his pay and allowances (including special and incentive pays) as an active officer, or his retired pay.

International Cooperation

SEC. 205. The Administration, under the foreign policy guidance of the President, may engage in a program of international cooperation in work done pursuant to this Act, and in the peaceful application of the results thereof, pursuant to agreements made by the President with the advice and consent of the Senate.

Reports to the Congress

SEC. 206. (a) The Administration shall submit to the President for transmittal to the Congress, semiannually and at such other times as it deems desirable, a report of its activities and accomplishments.

(b) The President shall transmit to the Congress in January of each year a report, which shall include (1) a comprehensive description of the programed activities and the accomplishments of all agencies of the United States in the field of aeronautics and space activities during the preceding calendar year, and (2) an evaluation of such activities and accomplishments in terms of the attainment of, or the failure to attain, the objectives described in section 102 (c) of this Act.

(c) Any report made under this section shall contain such recommendations for additional legislation as the Administrator or the President may consider necessary or desirable for the attainment of the objectives described in section 102 (c) of this Act.

(d) No information which has been classified for reasons of national security shall be included in any report made under this section, unless such information has been declassified by or pursuant to authorization given by, the President.

TITLE III—MISCELLANEOUS

National Advisory Committee for Aeronautics

SEC. 301. (a) The National Advisory Committee for Aeronautics, on the effective date of this section, shall cease to exist. On such date all functions, powers, duties, and obligations, and all real and personal property, personnel (other than members of the Committee), funds, and records of that organization, shall be transferred to the Administration.

(b) Section 2302 of title 10 of the United States Code is amended by striking out "or the Executive Secretary of the National Advisory Committee for Aeronautics" and inserting in lieu thereof "or the Administrator of the National Aeronautics and Space Administration"; and section 2303 of such title 10 is amended by striking out "The National Advisory Committee for Aeronautics" and inserting in lieu thereof "The National Aeronautics and Space Administration."

(c) The first section of the Act of August 26, 1950 (5 U.S.C. 22-1), is amended by striking out "the Director, National Advisory Committee for Aeronautics" and inserting in lieu thereof "the Administrator of the National Aeronautics and Space Administration," and by striking out "or National Advisory Committee for Aeronautics" and inserting in lieu thereof "or National Aeronautics and Space Administration."

(d) The Unitary Wind Tunnel Plan Act of 1949 (50 U. S. C. 511–515) is amended (1) by striking out "The National Advisory Committee for Aeronautics (hereinafter referred to as the 'Committee')" and inserting in lieu thereof "The Administrator of the National Aeronautics and Space Administration (hereinafter referred to as the 'Administrator')"; (2) by striking out "Committee" or "Committee's" wherever they appear and inserting in lieu thereof "Administrator" and "Administrator's," respectively; and (3) by striking out "its" wherever it appears and inserting in lieu thereof "his."

(e) This section shall take effect ninety days after the date of the enactment of this Act, or on any earlier date on which the Administrator shall determine, and announce by proclamation published in the Federal Register, that the Administration has been organized and is prepared to discharge the duties and exercise the powers conferred upon it by this Act.

Transfer of Related Functions

SEC. 302. (a) Subject to the provisions of this section, the President, for a period of four years after the date of enactment of this Act, may transfer to the Administration any functions (including powers, duties, activities, facilities, and parts of functions) of any other department or agency of the United States, or of any officer or organizational entity thereof, which relate primarily to the functions, powers, and duties of the Administration as prescribed by section 203 of this Act. In connection with any such transfer, the President may, under this section or other applicable authority, provide for appropriate transfers of records, property, civilian personnel, and funds.

(b) Whenever any such transfer is made before January 1, 1959, the President shall transmit to the Speaker of the House of Representatives and the President pro tempore of the Senate a full and complete report concerning the nature and effect of such transfer.

(c) After December 31, 1958, no transfer shall be made under this section until (1) a full and complete report concerning the nature and effect of such proposed transfer has been transmitted by the President to the Congress, and (2) the first period of sixty calendar days of regular session of the Congress following the date of receipt of such report by the Congress has expired without the adoption by the Congress of a concurrent resolution stating that the Congress does not favor such transfer.

Access to Information

SEC. 303. Information obtained or developed by the Administrator in the performance of his functions under this Act shall be made available for public inspection, except (A) information authorized or required by Federal statute to be withheld, and (B) information classified to protect the national security: *Provided*, That nothing in this Act authorize the withholding of information by the Administrator from the duly authorized committees of the Congress.

Security

SEC. 304. (a) The Administrator shall establish such security requirements, restrictions, and safeguards as he deems necessary in the interest of the national security. The Administrator may arrange with the Civil Service Commission for the conduct of such security or other personnel investigations of the Administration's officers, employees, and consultants, and its contractors and subcontractors and their officers and employees, actual or prospective, as he deems appropriate; and if any such investigation develops any data reflecting that the individual who is the subject thereof is of questionable loyalty the matter shall be referred to the Federal Bureau of Investigation for the conduct of a full field investigation, the results of which shall be furnished to the Administrator.

(b) The Atomic Energy Commission may authorize any of its employees, or employees of any contractor, prospective contractor, licensee, or prospective licensee of the Atomic Energy Commission or any other person authorized to have access to Restricted Data by the Atomic Energy Commission under subsection 145 b. of the Atomic Energy Act of 1954 (42 U. S. C. 2165 (b)), to permit any member, officer, or employee of the Council, or the Administrator, or any officer, employee, member of an advisory committee, contractor, subcontractor, or officer or employee of a contractor or subcontractor of the Administration, to have access to Restricted Data relating to aeronautical and space activities which are required in the performance of his duties and certified by the Council or the Administrator, as the case may be, but only if (1) the Council or Administrator or designee thereof has determined, in accordance with the established personnel security procedures and standards of the Council or Administration, that permitting such individual to have access to such Restricted Data will not endanger the common defense and security, and (2) the Council or Administrator or designee thereof finds that the established personnel and other security procedures and standards of the Council or Administration are adequate and in reasonable conformity to the standards established by the Atomic Energy Commission under section 145 of the Atomic Energy Act of 1954 (42 U. S. C. 2165). Any individual granted access to such Restricted Data pursuant to this subsection may exchange such Data with any individual who (A) is an officer or employee of the Department of Defense, or any department or agency thereof, or a member of the armed forces, or a contractor or subcontractor of any such department, agency, or armed force, or an officer or employee of any such contractor or subcontractor, and (B) has been authorized to have access to Restricted Data under the provisions of section 143 of the Atomic Energy Act of 1954 (42 U. S. C. 2163).

(c) Chapter 37 of title 18 of the United States Code (entitled Espionage and Censorship) is amended by—

(1) adding at the end thereof the following new section:

"§ 799. Violation of regulations of National Aeronautics and Space Administration

"Whoever willfully shall violate, attempt to violate, or conspire to violate any regulation or order promulgated by the Administrator of the National Aeronautics and Space Administration for the protection or security of any laboratory, station, base or other facility, or part thereof, or any aircraft, missile, spacecraft, or similar vehicle, or part thereof, or other property or equipment in the custody of the Administration, or any real or personal property or equipment in the custody of any contractor under any contract with the Administration or any subcontractor of any such contractor, shall be fined not more than $5,000, or imprisoned not more than one year, or both."

(2) adding at the end of the sectional analysis thereof the following New item:

"799. Violation of regulations of National Aeronautics and Space Administration."

(d) Section 1114 of title 18 of the United States Code is amended by inserting immediately before "while engaged in the performance of his official duties" the following: "or any officer or employee of the National Aeronautics and Space Administration directed to guard and protect property of the United States under the administration and control of the National Aeronautics and Space Administration."

(e) The Administrator may direct such of the officers and employees of the Administration as he deems necessary in the public interest to carry firearms while in the conduct of their official duties. The Administrator may also authorize such of those employees of the contractors and subcontractors of the Administration engaged in the protection of property owned by the United States and located at facilities owned by or contracted to the United States as he deems necessary in the public interest, to carry firearms while in the conduct of their official duties.

Property Rights in Inventions

SEC. 305. (a) Whenever any invention is made in the performance of any work under any contract of the Administration, and the Administrator determines that—

(1) the person who made the invention was employed or assigned to perform research, development, or exploration work and the invention is related to the work he was employed or assigned to perform, or that it was within the scope of his employment duties, whether or not it was made during working hours, or with a contribution by the Government of the use of Government facilities, equipment, materials, allocated funds, information proprietary to the Government, or services of Government employees during working hours; or

(2) the person who made the invention was not employed or assigned to perform research, development, or exploration work, but the invention is nevertheless related to the contract, or to the work or duties he was employed or assigned to perform, and was made during working hours, or with a contribution from the Government of the sort referred to in clause (1),

such invention shall be the exclusive property of the United States, and if such invention is

patentable a patent therefor shall be issued to the United States upon application made by the Administrator, unless the Administrator waives all or any part of the rights of the United States to such invention in conformity with the provisions of subsection (f) of this section.

(b) Each contract entered into by the Administrator with any party for the performance of any work shall contain effective provisions under which such party shall furnish promptly to the Administrator a written report containing full and complete technical information concerning any invention, discovery, improvement, or innovation which may be made in the performance of any such work.

(c) No patent may be issued to any applicant other than the Administrator for any invention which appears to the Commissioner of Patents to have significant utility in the conduct of aeronautical and space activities unless the applicant files with the Commissioner, with the application or within thirty days after request therefor by the Commissioner, a written statement executed under oath setting forth the full facts concerning the circumstances under which such invention was made and stating the relationship (if any) of such invention to the performance of any work under any contract of the Administration. Copies of each such statement and the application to which it relates shall be transmitted forthwith by the Commissioner to the Administrator.

(d) Upon any application as to which any such statement has been transmitted to the Administrator, the Commissioner may, if the invention is patentable, issue a patent to the applicant unless the Administrator, within ninety days after receipt of such application and statement, requests that such patent be issued to him on behalf of the United States. If, within such time, the Administrator files such a request with the Commissioner, the Commissioner shall transmit notice thereof to the applicant, and shall issue such patent to the Administrator unless the applicant within thirty days after receipt of such notice requests a hearing before a Board of Patent Interferences on the question whether the Administrator is entitled under this section to receive such patent. The Board may hear and determine, in accordance with rules and procedures established for interference cases, the question so presented, and its determination shall be subject to appeal by the applicant or by the Administrator to the Court of Customs and Patent Appeals in accordance with procedures governing appeals from decisions of the Board of Patent Interferences in other proceedings.

(e) Whenever any patent has been issued to any applicant in conformity with subsection (d), and the Administrator thereafter has reason to believe that the statement filed by the applicant in connection therewith contained any false representation of any material fact, the Administrator within five years after the date of issuance of such patent may file with the Commissioner a request for the transfer to the Administrator of title to such patent on the records of the Commissioner. Notice of any such request shall be transmitted by the Commissioner to the owner of record of such patent, and title to such patent shall be so transferred to the Administrator unless within thirty days after receipt of such notice such owner of record requests a hearing before a Board of Patent Interferences on the question whether any such false representation was contained in such statement. Such question shall be heard and determined, and determination thereof shall be subject to review, in the manner prescribed by subsection (d) for questions arising thereunder. No request made by the Administrator under this subsection for the transfer of title to any patent, and no prosecution for the violation of any criminal statute, shall be barred by any failure of the Administrator to make a request under subsection (d) for the issuance of such patent to him, or by any notice previously given by the Administrator stating that he had no objection to the issuance of such patent to the applicant therefor.

(f) Under such regulations in conformity with this subsection as the Administrator shall prescribe, he may waive all or any part of the rights of the United States under this section with respect to any invention or class of inventions made or which may be made by any person or class of persons in the performance of any work required by any contract of the Administration if the Administrator determines that the interests of the United States shall be served thereby. Any such waiver may be made upon such terms and under such conditions as the Administrator shall determine to be required for the protection of the interests of the United States. Each such waiver made with respect to any invention shall be subject to the reservation by the Administrator of an irrevocable, nonexclusive, nontransferrable, royalty-free license for the practice of such invention throughout the world by or on behalf of the United States or any foreign government pursuant to any treaty or agreement with the United States. Each proposal for any waiver under this subsection shall be referred to an Inventions and Contributions Board which shall be established by the Administrator within the Administration. Such Board shall accord to each interested party an opportunity for hearing, and shall transmit to the Administrator its findings of fact with respect to such proposal and its recommendations for action to be taken with respect thereto.

(g) The Administrator shall determine, and promulgate regulations specifying, the terms and conditions upon which licenses will be granted by the Administration for the practice by any person (other than an agency of the United States) of any invention for which the Administrator holds a patent on behalf of the United States.

(h) The Administrator is authorized to take all suitable and necessary steps to protect any invention or discovery to which he has title, and to require that contractors or persons who retain title to inventions or discoveries under this section protect the inventions or discoveries to which the Administration has or may acquire a license of use.

(i) The administration shall be considered a defense agency of the United States for the purpose of chapter 17 of title 35 of the United States Code.

(j) As used in this section—

(1) the term "person" means any individual, partnership, corporation, association, institution, or other entity;

(2) the term "contract" means any actual or proposed contract, agreement, understanding, or other arrangement, and includes any assignment, substitution of parties, or subcontract executed or entered into thereunder; and

(3) the term "made," when used in relation to any invention, means the conception or first actual reduction to practice of such invention.

Contributions Awards

SEC. 306. (a) Subject to the provisions of this section, the Administrator is authorized, upon his own initiative or upon application of any person, to make a monetary award, in such amount and upon such terms as he shall determine to be warranted, to any person (as defined by section 305) for any scientific or technical contribution to the Administration which is determined by the Administrator to have significant value in the conduct of aeronautical and space activities. Each application made for any such award shall be referred to the Inventions and Contributions Board established under section 305 of this Act. Such Board shall accord to each such applicant an opportunity for hearing upon such application, and shall transmit to the Administrator its recommendation as to the terms of the award, if any, to be made to such applicant for such contribution. In determining the terms and conditions of any award the Administrator shall take into account—

(1) the value of the contribution to the United States;

(2) the aggregate amount of any sums which have been expended by the applicant for the development of such contribution;

(3) the amount of any compensation (other than salary received for services rendered as an officer or employee of the Government) previously received by the applicant for or on account of the use of such contribution by the United States; and

(4) such other factors as the Administrator shall determine to be material.

(b) If more than one applicant under subsection (a) claims an interest in the same contribution, the Administrator shall ascertain and determine the respective interests of such applicants, and shall apportion any award to be made with respect to such contribution among such applicants in such proportions as he shall determine to be equitable. No award may be made under subsection (a) with respect to any contribution—

(1) unless the applicant surrenders, by such means as the Administrator shall determine to be effective, all claims which such applicant may have to receive any compensation (other than the award made under this section) for the use of such contribution or any element thereof at any time by or on behalf of the United States, or by or on behalf of any foreign government pursuant to any treaty or agreement with the United States, within the United States or at any other place;

(2) in any amount exceeding $100,000, unless the Administrator has transmitted to the appropriate committees of the Congress a full and complete report concerning the amount and terms of, and the basis for, such proposed award, and thirty calendar days of regular session of the Congress have expired after receipt of such report by such committees.

Appropriations

SEC. 307. (a) There are hereby authorized to be appropriated such sums as may be necessary to carry out this Act, except that nothing in this Act shall authorize the appropriation of any amount for (1) the acquisition or condemnation of any real property, or (2) any other item of a capital nature (such as plant or facility acquisition, construction, or expansion) which exceeds $250,000. Sums appropriated pursuant to this subsection for the construction of facilities, or for research and development activities, shall remain available until expended.

(b) Any funds appropriated for the construction of facilities may be used for emergency repairs of existing facilities when such existing facilities are made inoperative by major breakdown, accident, or other circumstances and such repairs are deemed by the Administrator to be of greater urgency than the construction of new facilities.

Speaker of the House of Representatives.

Vice President of the United States and President of the Senate.

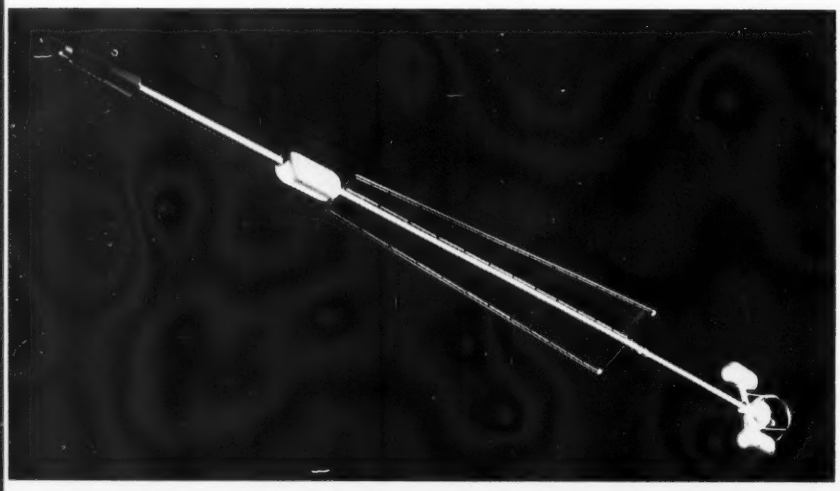
NACA designs for tomorrow

Four proposals for recoverable satellites and hypothetical designs for space vehicles with electrical and nuclear propulsion systems released

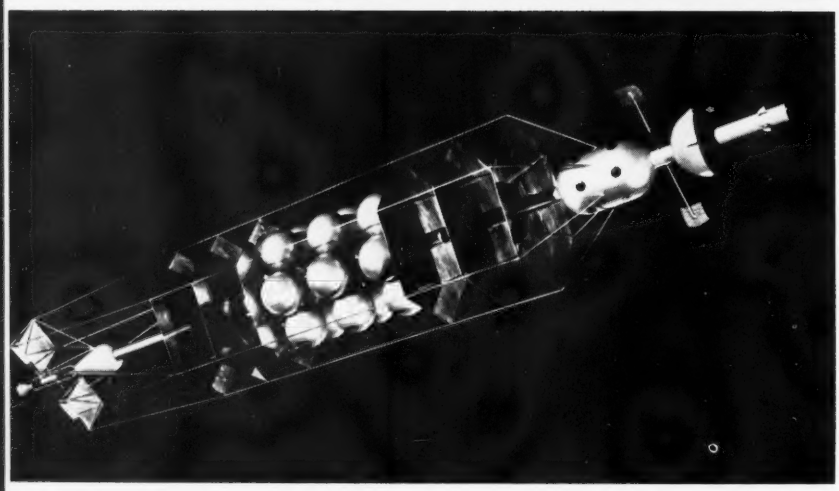
SOME CONCRETE evidence as to the thinking of the National Advisory Committee for Aeronautics, now charged with responsibility for the national civilian space flight program (see page 39), with regard to future astronautical projects is provided in recently released NACA satellite designs and models of hypothetical space craft utilizing electrical propulsion and nuclear rocket systems, shown on these pages.

Four different NACA designs for recoverable re-entry satellites have been shown—a relatively simple ballistic cone, a manned hemisphere, and delta-wing and boat-shaped manned gliders.

The simplest of these designs, the blunt-nosed



ELECTRICAL PROPULSION VEHICLE. Left to right, nuclear reactor (at tip), neutron shield, heat exchanger, gamma ray shield, propellant, turbogenerating equipment for working fluid (in tank near center), and (far right), two crew cabins, a landing vehicle similar to hemispherical re-entry satellite, and ring-shaped propellant accelerator.



NUCLEAR ROCKET. Arrangement is roughly similar to that used in electrical propulsion system except that spherical tanks for liquid hydrogen, used as propellant, are clustered at center, with shields to protect the tanks from direct solar radiation and reactor heat.

cone, would carry a payload capsule within a copper, heat-absorbing shield, and separated from the shield by an air gap and surface insulation. This design, which would probably carry only an instrument payload, could be equipped with retro-rockets to start re-entry and a parachute to cut the shock of impact.

More complicated, the hemispheric design would carry controls, instruments and a man in a similarly insulated compartment, which would employ a beryllium oxide shield. The man, shown in position for ascent to orbit, could rotate 180 deg vertically for support against an estimated minimum deceleration of 8 g's during re-entry. The satellite would carry retro-rockets to start re-entry, fins for roll stabilization, equipment for controlling internal atmosphere and temperature, and a parachute, actuated at low altitude, to cut the shock of impact and aid in recovery.

The gliders are radiation-cooled designs with insulated internal structure and cabin. They employ blunt and rounded surfaces where practical to minimize aerodynamic heating during relatively long returns through the atmosphere. They re-enter at a high angle of attack (about 55 deg) to gain as much lift and as low an aerodynamic heating rate as possible. (See August, 1958, ASTRONAUTICS, page 34).

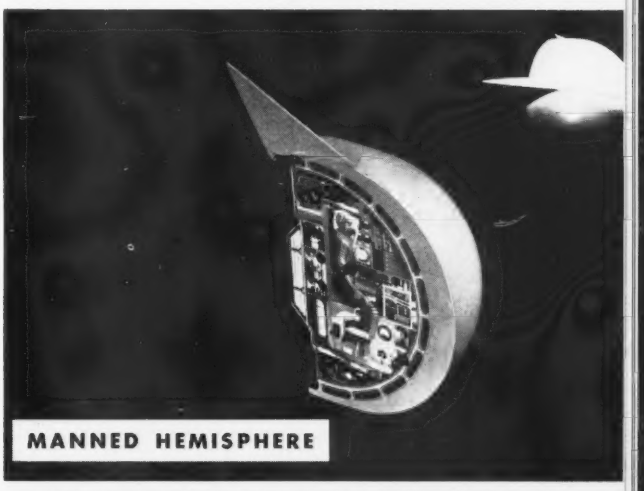
Small Retro-Rockets Start Re-entry

Both use a large rocket motor for final boost to satellite speed and small retro-rockets to start re-entry; reaction jets for spatial stabilization; equipment for controlling cabin pressure and temperature; instrumentation for automatic flight; and more or less conventional pilot seats, because maximum deceleration during re-entry should be only about 2 g's. They can maneuver during descent, and consequently allow some choice of landing area. Thus the boat design would probably land on water.

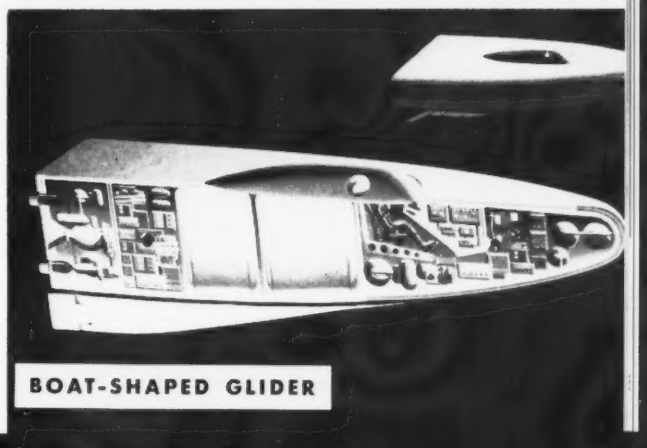
The delta-wing design has the advantage of providing greater control in landing than the boat-shaped type, but aerodynamic heating could be greater, especially at the nose and leading edges of the wings.

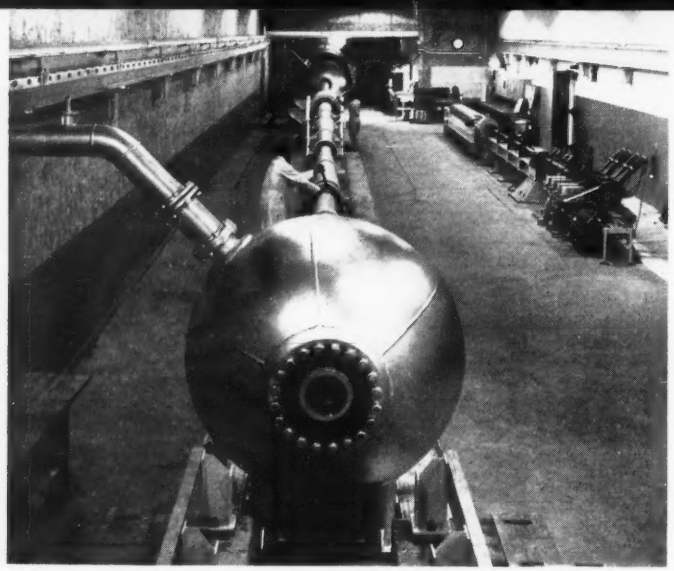
While NACA's hypothetical space vehicle models do not represent specific designs of prototype vehicles, they do show the basic components which might be used in electrical propulsion or nuclear rocket systems.

BALLISTIC CONE


MANNED HEMISPHERE

DELTA-WING GLIDER


BOAT-SHAPED GLIDER

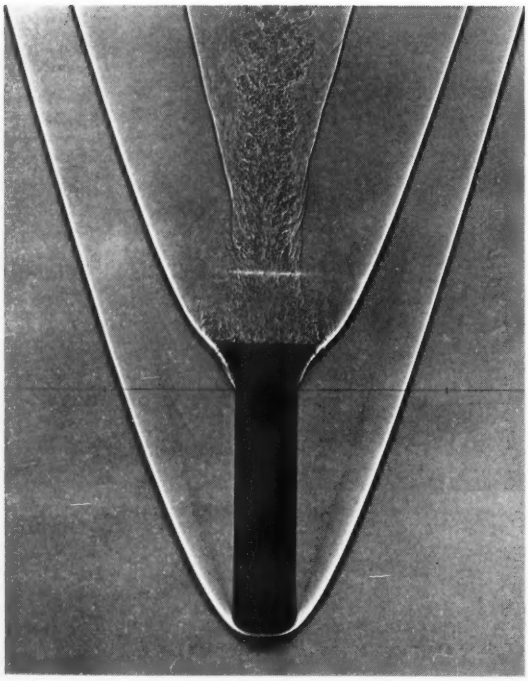


Newest research tool at Ames is this hypervelocity ballistic range. Light-gas gun capable of launching $^{3}/_{4}$-in. aerodynamic models at speeds up to 16,000 mph is located between sphere in foreground and 500-ft long, 8-ft diam tank in rear through which models fly during tests.

NACA Ames Aeronautical Laboratory

Breeding ground for space flight

By Irwin Hersey



Stability studies are made with gun-launched models in Ames supersonic free-flight wind tunnel. Here, shock wave generated by blunt-nosed cylinder moving at Mach 7 in tunnel has been stopped by shadowgraph photography.

MOFFETT FIELD, Calif.—The 1958 triennial inspection of the Ames Aeronautical Laboratory of the National Advisory Committee for Aeronautics here in mid-July was of unusual significance this year in that it came as Senate and House conferees were putting the final touches on a bill which turned NACA into the nation's civilian space agency (see page 39).

Devoted primarily to NACA astronautical research, the inspection indicated what work the agency has already done in this field and, even more important, provided a clue as to what direction this work is likely to take in the future.

Described Areas of Activity

During the course of the inspection, Ames personnel provided full-scale rundowns on nine different areas of activity—earth satellites, aerophysics, aerodynamic heating, hypervelocity and entry research techniques, stability during atmosphere entry, flight research for space craft, space propulsion systems, piloting problems during entry, and supersonic aircraft. These discussions covered work carried out not only at Ames, but also at the two other NACA labs—Lewis Flight Propulsion Lab and Langley Aeronautical Lab.

Equipment of this type is being used to solve entry piloting and control problems. Simulated cockpit (left background) rolls, pitches and yaws in response to signals from electronic equipment in this control room.

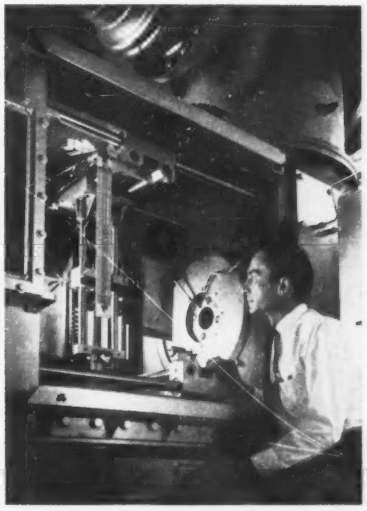
Some of the equipment in use at Ames to solve major astronautical problems are pictured on these and the following pages.

Listed Problems Still to Be Solved

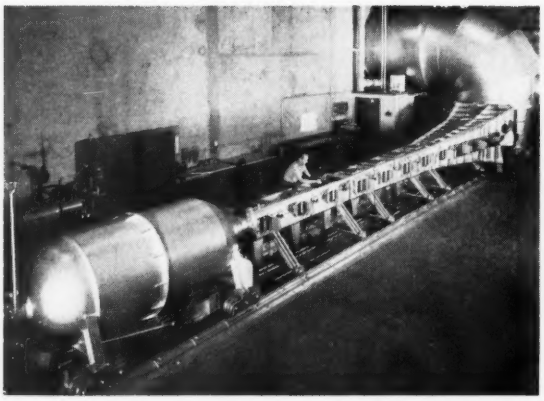
In an introductory address prior to the inspection, which attracted more than 750 newsmen, military brass, congressional figures and industry leaders, NACA Director Hugh Dryden compared aeronautical and astronautical research, and ran through some of the problems which must be solved before true space flight can be achieved.

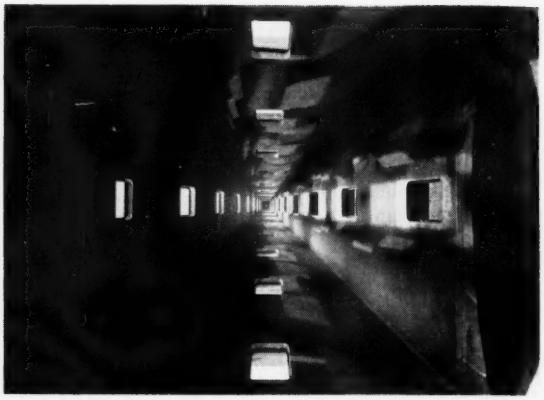
"At first, before we put large space stations into orbit," he noted, "we will be dealing with vehicles which are launched through the atmosphere and which must re-enter the atmosphere, be slowed down without destruction by heating, and finally land. The major problems of these vehicles are akin to those of present airplanes, differing only in degree. Their solution requires only an extension of

This ion accelerator is used to study the effects of ionized particles of the type which might be encountered in space on space vehicle materials.



Aerodynamic studies at simulated high altitudes are carried out in this low density wind tunnel. Circular exit of supersonic nozzle capable of expelling low density air at speeds up to Mach 6 is at center right. Apparatus at left center positions model in air stream.





Atmosphere entry simulator, combining specially shaped supersonic nozzle with a high-speed gun, duplicates flight of a ballistic missile as well as changing density of atmosphere through which it travels. Striking study in perspective is provided by photo at right, looking upstream into simulator. Wall openings permit shadowgraph photos to be taken during tests.

research into new regions of speed, temperature and pressure. These vehicles will always be needed, as will our present type of airplanes.

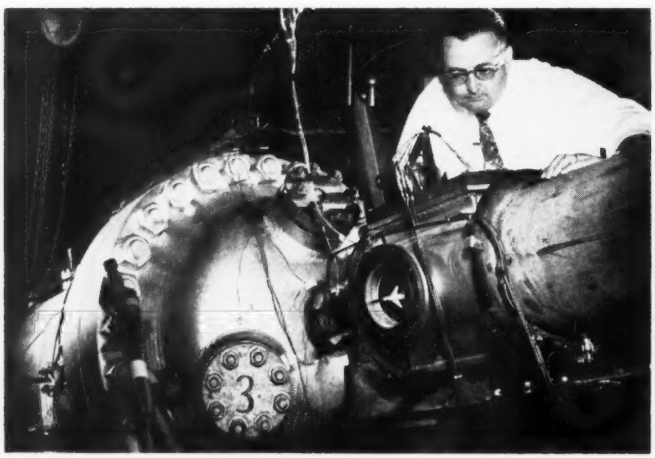
"As space technology advances, the true space or interplanetary vehicles will appear. In the development of these, new problems will have become dominant. The structures no longer will be subject to large forces over large areas. They will use light structural members and involve new materials which seem strange at present.

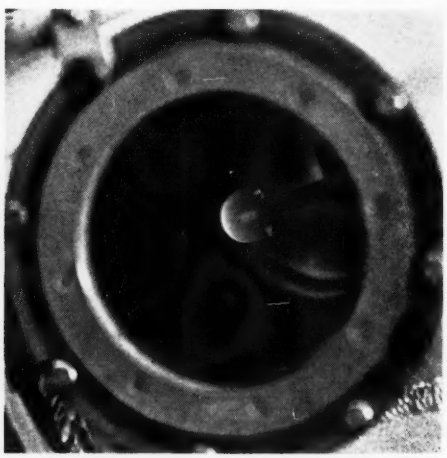
"Once space vehicles have completed the first phase of their journey, propulsion will no longer require large thrusts, and fuel economy will be the dominant consideration. Some type of electrical propulsion system, ion or otherwise, becomes attractive. Our engineering compromises will move toward engines of thousands of pounds weight per pound of thrust. However, fuel consumption of as little as 1 per cent of those associated with present powerplants will be achieved.

Require Different Solutions

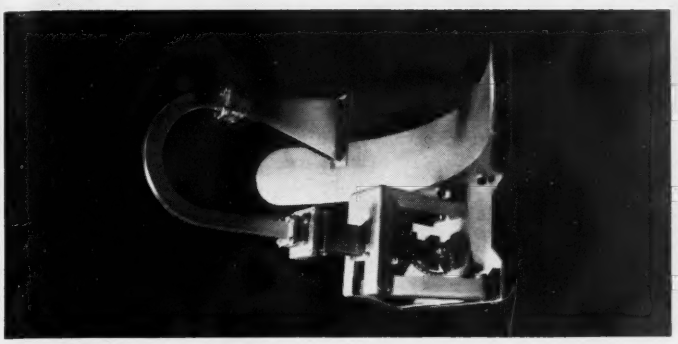
"The provision of internal power from nuclear reactors or solar power, navigation, guidance and control, communication, suitable environment for man—these and many other problems will require very different solutions from those we now use.

"The greatest demands will be made on our research and development capabilities as we venture farther and farther into space," he concluded.





Temperatures up to 2500 F can be attained in this pebble-bed heater, used for aerodynamic heating studies at Ames. Air stream is forced through ceramic or refractory "marbles" at white heat in cylindrical tank at left and then expanded to speeds up to Mach 10 through special nozzle. Photo at right shows test section, in which miniature steel nose cone glows at 2000 F in test.



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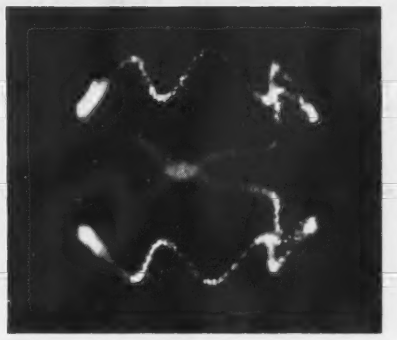

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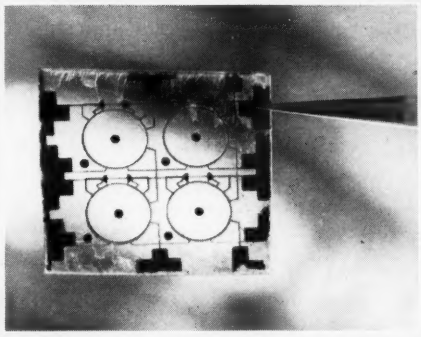

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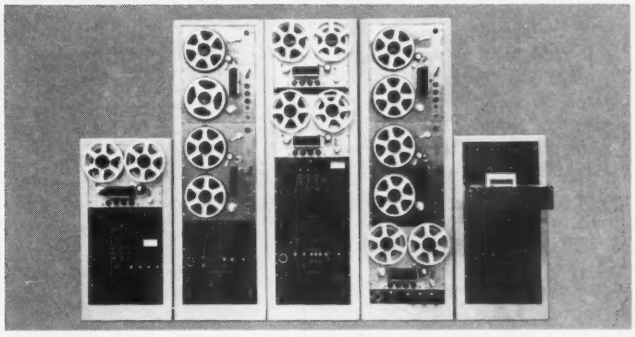
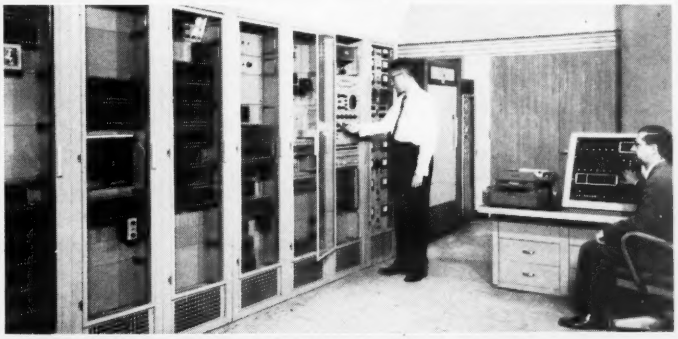
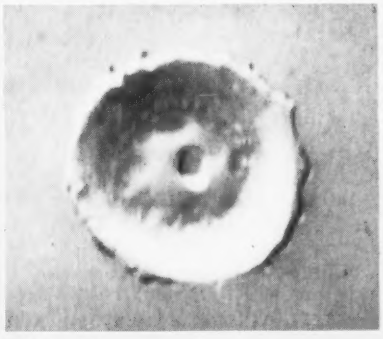


Ground based data handling equipment for processing analog and digital reconnaissance information.



Data conversion system for digitizing and processing telemetered missile test data.



Electron micrograph of impact produced on aluminum coated glass by a 1 micron diameter particle traveling at 7,000 feet per second.

Pictorial **PROGRESS REPORT**

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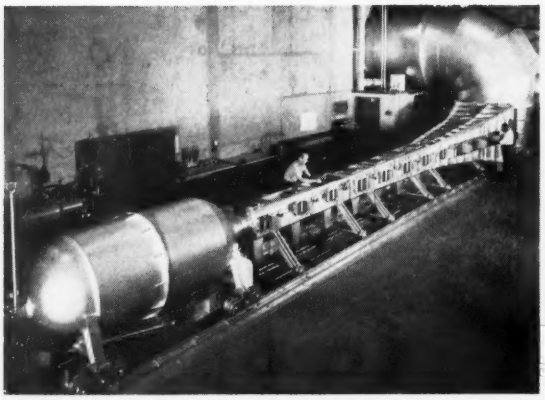
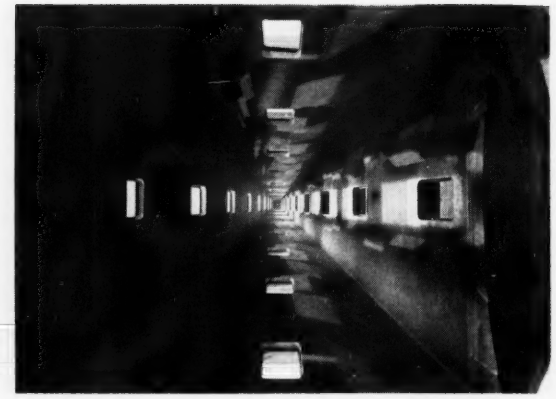
- Digital Computers and Control Systems
- Communications and Navigation Systems
- Guided Missile Research and Development
- Infrared Systems
- Electronic Countermeasures
- Electronic Instrumentation and Test Equipment
- Basic Electronic and Aeronautical Research

The Ramo-Wooldridge Corporation

LOS ANGELES 45, CALIFORNIA





Atmosphere entry simulator, combining specially shaped supersonic nozzle with a high-speed gun, duplicates flight of a ballistic missile as well as changing density of atmosphere through which it travels. Striking study in perspective is provided by photo at right, looking upstream into simulator. Wall openings permit shadowgraph photos to be taken during tests.

research into new regions of speed, temperature and pressure. These vehicles will always be needed, as will our present type of airplanes.

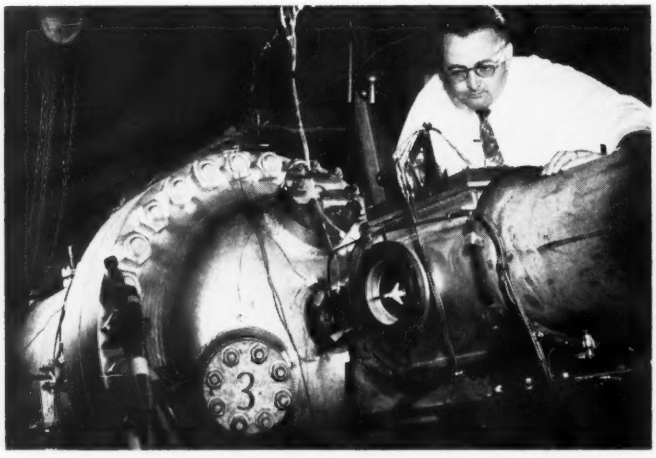
"As space technology advances, the true space or interplanetary vehicles will appear. In the development of these, new problems will have become dominant. The structures no longer will be subject to large forces over large areas. They will use light structural members and involve new materials which seem strange at present.

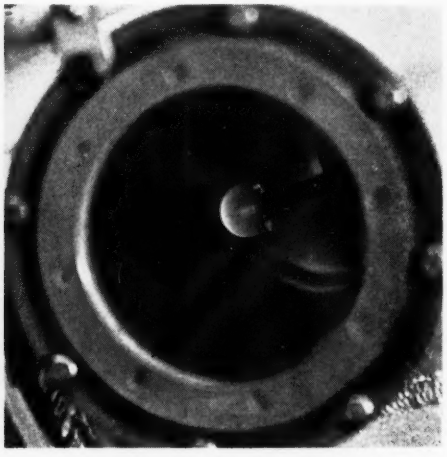
"Once space vehicles have completed the first phase of their journey, propulsion will no longer require large thrusts, and fuel economy will be the dominant consideration. Some type of electrical propulsion system, ion or otherwise, becomes attractive. Our engineering compromises will move toward engines of thousands of pounds weight per pound of thrust. However, fuel consumption of as little as 1 per cent of those associated with present powerplants will be achieved.

Require Different Solutions

"The provision of internal power from nuclear reactors or solar power, navigation, guidance and control, communication, suitable environment for man—these and many other problems will require very different solutions from those we now use.

"The greatest demands will be made on our research and development capabilities as we venture farther and farther into space," he concluded.





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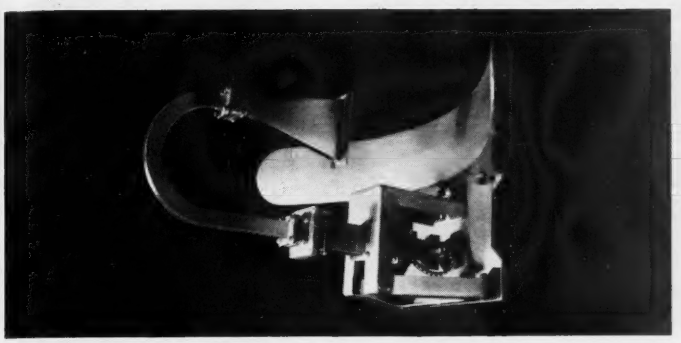

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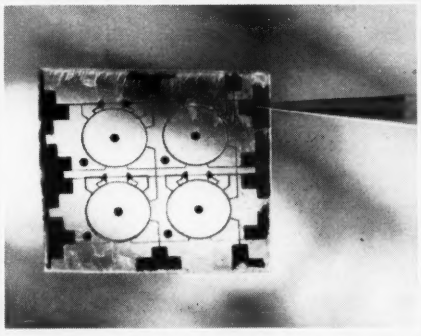

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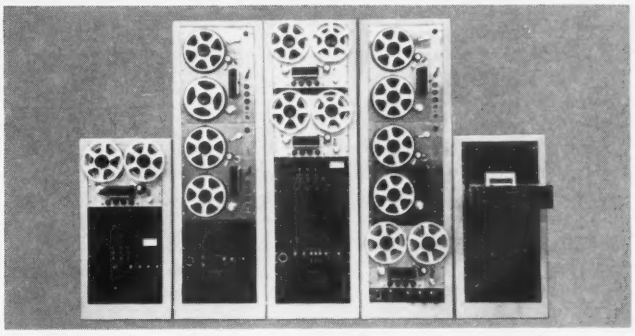

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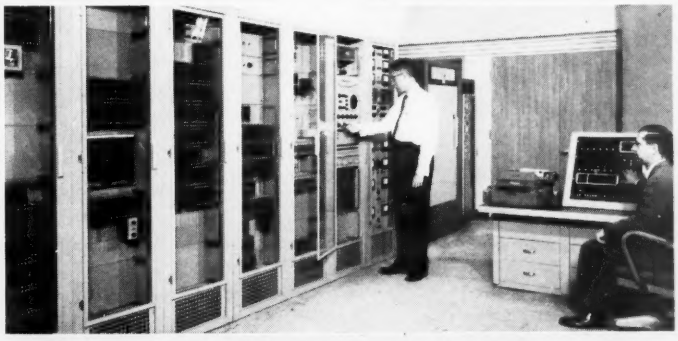

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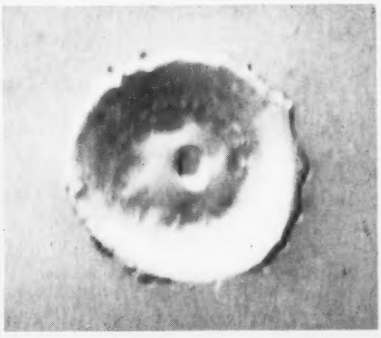

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The Ramo-Wooldridge Corporation

LOS ANGELES 45, CALIFORNIA

Missile market

BY ROBERT H. KENMORE

THE MISSILE index continued its upward surge in July and broke into the uncharted area of new highs. Only one stock of the 23 in the index failed to share in the advance, as bullish psychology gripped investors and Wall Street focused its attention on the "war babies." While new words of caution might be voiced about the dangers of rushing in to join the eager throng of investors who see the market going up in the face of bad news and are afraid of being left out, investors in missile securities have much in their favor.

As a glance at the chart on the right will show, the last two years have seen a steady 200-point advance in the missile index, while the general market, represented by the Dow-Jones Industrials, has merely churned within a relatively narrow trading range. (This type of performance was predicted in the October, 1957, column.)

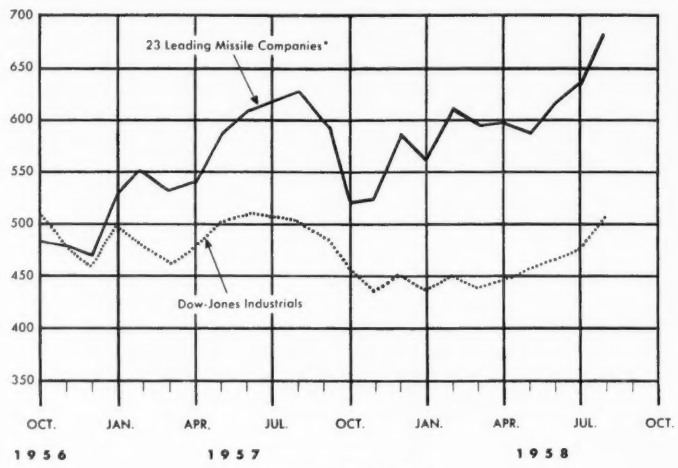
Actually, missile securities have had four very good reasons to go up: (1) Defense Dept. contract awards have risen dramatically, increasing sales and backlogs; (2) production contracts have been increasing in relation to less profitable R&D work, resulting in improving profit margins; (3) international tension and Russian scientific achievements indicated this growth would continue to accelerate; and (4) investors and their advisers have gradually come to recognize the industry's potential as publicity about missiles and satellites intensified.

This has been a sound background for higher prices. In addition, there is no reason to believe any of these factors will disappear in the future and the scene is thus set for additional price appreciation based on continuing betterment in the fundamental values of missile companies. This would be true even in a static market. A continuation of bullish feeling, however, would serve to further this action, with stocks rising quicker and going higher.

° ° °

Missile investments sometime make for strange bedfellows, as the discussion below would indicate. Both of the companies mentioned herein have a big stake in missiles, and both are considered unusually attractive—but there the similarity ends. One has been in business 67 years; the other, three years. One has sales of $70 million; the other $3 million. These are but two of the many contrasts that stand out. What their significance is, however, the investor will have to judge for himself.

THE MARKET AT A GLANCE



*Index compiled June, 1955

	August 1958	July 1958	% Change	August 1957	% Change
Dow-Jones Industrials	505	475	+6.3	505	—
Missile Index	678	638	+6.3	628	+8.0

The first company is *Emerson Electric Mfg. Co.*, with 67 years of fascinating history behind it, not all smooth sailing. Traditionally a small manufacturer of fractional horsepower motors, sales exceeded $5 million in only two of the company's first fifty years through 1940. Then came the war, and by 1944, sales exceeded $110 million! Emerson had suddenly blossomed out into one of the largest producers of war material in the U.S., and *the* largest producer of airplane gun turrets. Came 1946 and sales slid back to $12 million. However, the roller-coaster ride had taught a valuable lesson, and sound and steady growth has been the story since then, with sales this fiscal year (ending Sept. 30) expected to top the $70 million mark.

In the missile field, Emerson has come far. With prime contracts for the Honest John and Little John, the company's Electronics and Avionics Div. accounted for 37 per cent of fiscal '57 sales of $65 million, and profit margins are continually increasing with increased volume. This Division also produces a fire control system and the fuselage section for Convair's B-58, nose fuselage sections for McDonnell's F-101B, and a mortar location radar system. Having learned of the perils of Government work (while $108 million of 1944 volume represented sales to the military, this figure plunged to only 1^1/_2$ million by 1947), Emerson has not neglected its commercial line of electrical products, which now account for 60 per cent of sales. The company ranks today as one of the largest manufacturers of electric motors and electric fans. Most of its motors are used in refrigeration and air conditioning, two fields with enviable future growth trends.

Company finances are extremely strong. With pretax earnings running at about 8 per cent of sales, the company earned $2.95 per share in the nine months ending June 30, when operating profits were up 8.7 per cent over the same period a year ago. Earnings for the full year will probably be around $3.50 per share and the stock is thus selling at a very conservative 11 times earning. The $1.60 dividend is amply covered and provides a satisfactory 4.2 per cent yield. Working capital is sufficient to sustain an even higher volume of busi-

(CONTINUED ON PAGE 90)

Missiles designed to soar out of this world

...are sped by liquid oxygen from LINDE

Oil, kerosene, and alcohol "burn" by combining chemically with oxygen from the air. But it takes pure oxygen with these fuels to speed rocket planes faster than sound . . . to drive missiles beyond the earth's atmosphere.

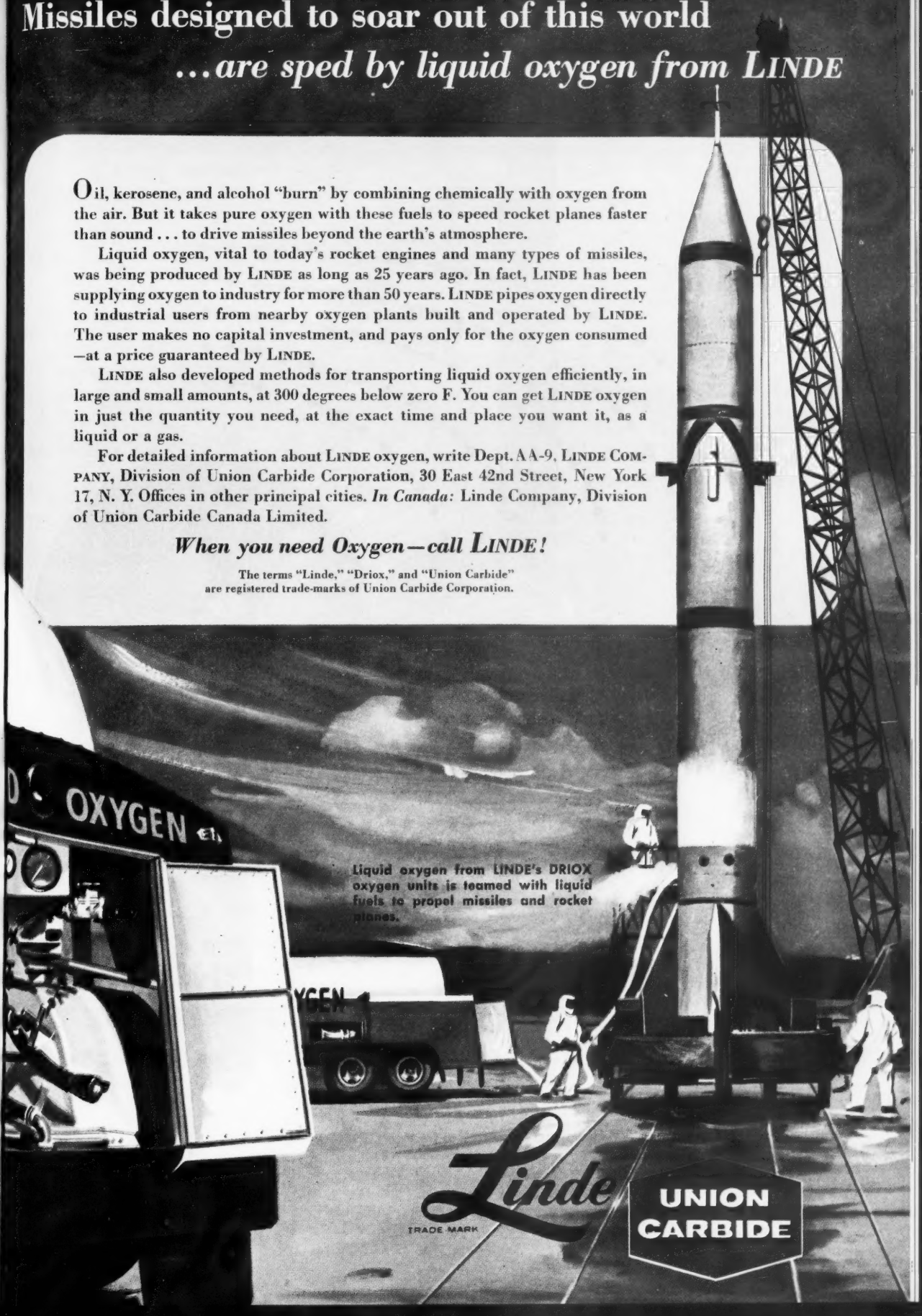
Liquid oxygen, vital to today's rocket engines and many types of missiles, was being produced by LINDE as long as 25 years ago. In fact, LINDE has been supplying oxygen to industry for more than 50 years. LINDE pipes oxygen directly to industrial users from nearby oxygen plants built and operated by LINDE. The user makes no capital investment, and pays only for the oxygen consumed —at a price guaranteed by LINDE.

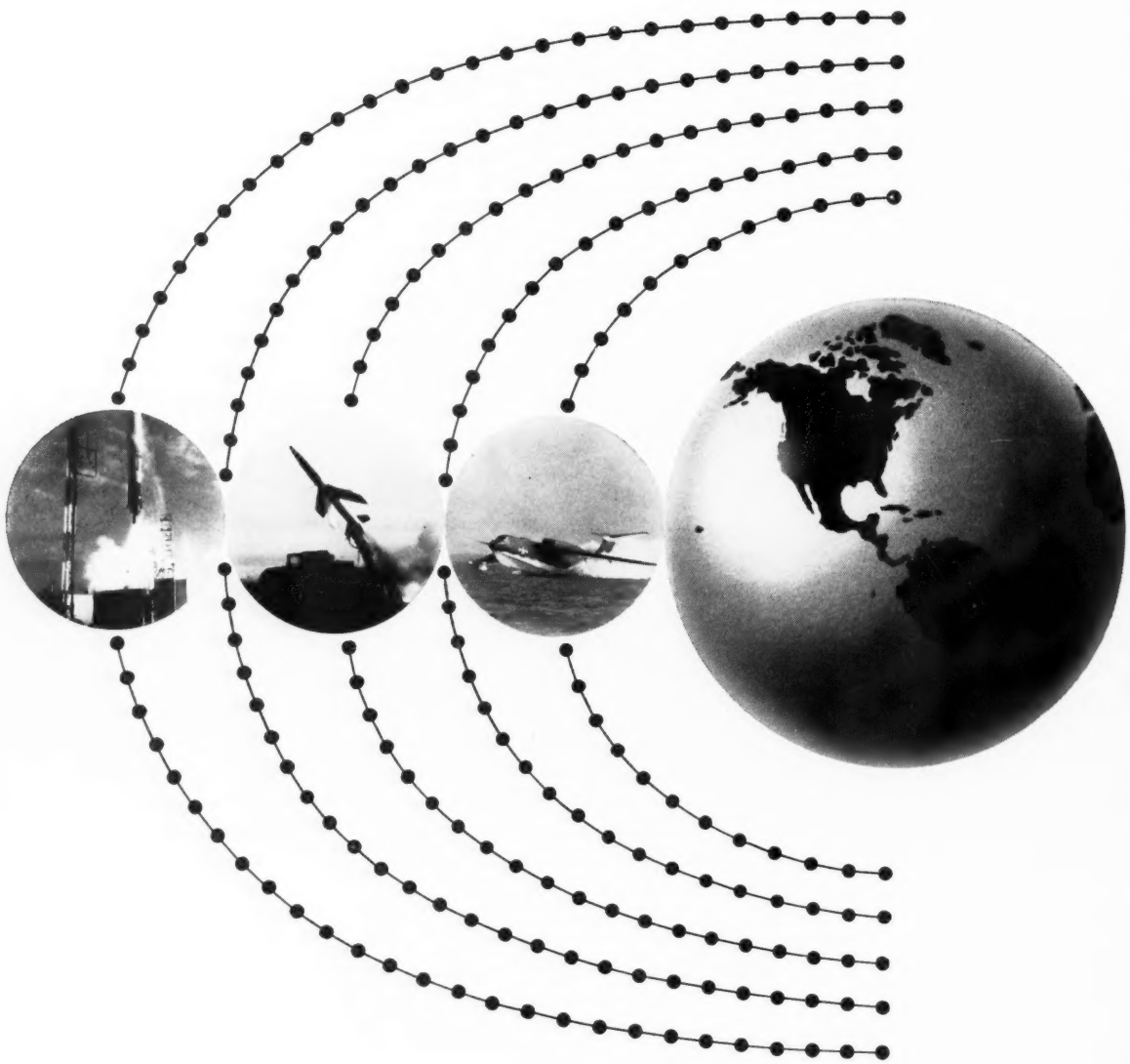
LINDE also developed methods for transporting liquid oxygen efficiently, in large and small amounts, at 300 degrees below zero F. You can get LINDE oxygen in just the quantity you need, at the exact time and place you want it, as a liquid or a gas.

For detailed information about LINDE oxygen, write Dept. AA-9, LINDE COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y. Offices in other principal cities. *In Canada:* Linde Company, Division of Union Carbide Canada Limited.

When you need Oxygen—call LINDE!

The terms "Linde," "Driox," and "Union Carbide" are registered trade-marks of Union Carbide Corporation.


OXYGEN
Liquid oxygen from LINDE's DRIOX oxygen units is teamed with liquid fuels to propel missiles and rocket planes.
Linde
TRADE-MARK
UNION CARBIDE



OUR WORLD

At Martin, it is the creation of aircraft, missile and research systems for the Army, Navy, Air Force and astroscientific branches of our government for operations on land, sea and air—and in outer space.

We produce these systems in three major facilities—in Baltimore, Denver and Orlando—including two of the newest and most advanced missile development centers in the world.

Those facilities are staffed by engineers and scientists aggregating better than 30,000 man-years of experience in the design and production of missiles, rockets and related electronics systems.

They constitute one of the country's most valuable resources devoted exclusively to the security of our world and its future progress in the exploration of space.

MARTIN
BALTIMORE·DENVER·ORLANDO

A Solid Proposal

(CONTINUED FROM PAGE 38)

as the nozzle, ignition system, connecting parts and guidance component, would come prepackaged for assembly with the bulk of the motor. Other stages, being more conventional in size, could be delivered to the launching site assembled or could also be loaded with propellant and tested and assembled at the site.

Building a rocket several hundred feet long would be quite a feat in ordinary terrain. For this reason, the rocket and launcher would be built either on the face of a cliff or in a hole, such as a mine shaft.

Making a practical rocket engine in this way is, of course, speculative, but we think it can be done if a mobile processing plant of this type were to be developed.

Contini Heads New Human Factors Society

Renato Contini of New York Univ. has been elected president of the Human Factors Society of America, a new national professional group concerned with man-machine problems. Other officers are John Lyman, UCLA, vice-president; Paul Cheatham, ONR, secretary; and Donald W. Conover, Convair, treasurer. Arnold Small of Convair is president-elect. Membership inquiries may be addressed to the society at P.O. Box 24032, Los Angeles.

R-W, Thiokol, Aerojet, NAA, Avco Minuteman Contractors

After a year of study, the Air Force has made its Ballistic Missile Div. prime manager for Minuteman, with Ramo-Wooldridge as technical assistance manager, and selected these companies to do research and development on the three-stage, solid propellant ICBM:

1. First stage: Thiokol Chemical Corp., with limited backup by Aerojet-General.

2. Second and third stages: Aerojet, with a backup program by Thiokol on both stages and a limited research program by Hercules Powder Co. (ABL) on double-base propellant for the third stage.

3. Guidance: Autonetics Div. of North American Aviation.

4. Nose Cone: Avco Mfg. Co., which is also developing nose cones for Titan and Polaris.

Contracts, for amounts not yet announced, are expected to be let to these companies as soon as DOD releases funds to the Air Force.

ADVANCED INERTIAL GUIDANCE

Complete systems or components for aircraft, missiles and spacecraft

To design and produce extremely accurate inertial guidance systems requires a complex combination of engineering and manufacturing skills. Each component must be developed to meet the accuracy needed for the system's mission.

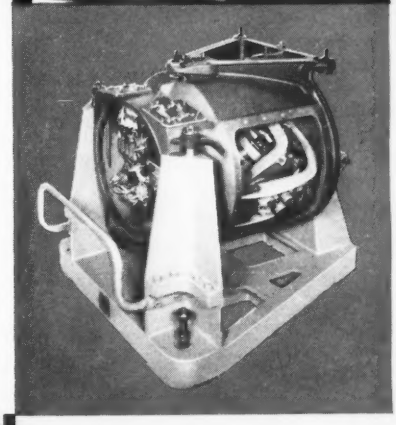
The long background in gyroscopics, electronics and computation has made it possible for Sperry to design and produce advanced inertial systems for some of our country's most modern weapons of defense. Other Sperry inertial systems will, one day, allow man to explore space.

On these pages are highlighted some of Sperry's recent achievements in inertial guidance. If you have a systems problem or are interested in individual components, write our Air Armament Division for further information.

CONVAIR'S B-58 HUSTLER with Sperry inertial navigation system will be able to navigate undetected for thousands of miles to exact target. Most nearly automatic airplane yet developed and requiring only a 3-man crew, the B-58 will fly faster than sound at altitudes well over 50,000 feet.

HYPERSONIC, ROCKET-POWERED X-15 manned research aircraft by North American is designed to explore near space. Sperry inertial system, developed for USAF, will give pilot data for navigating and maneuvering the NACA-sponsored X-15 with extreme accuracy at speeds of one mile per second.

UNDER MICROSCOPE. Sperry employee assembles floated gyros under specially-designed hood and in sealed pressurized room. Since even dust speck might cause serious error in a long-range mission, every precaution is taken in the production of these critical units.



COMPACT Sperry stable platform mounts three advanced floated gyros. Nerve center of the inertial system, platform serves as fixed space reference in flight for maintenance of prescribed course.

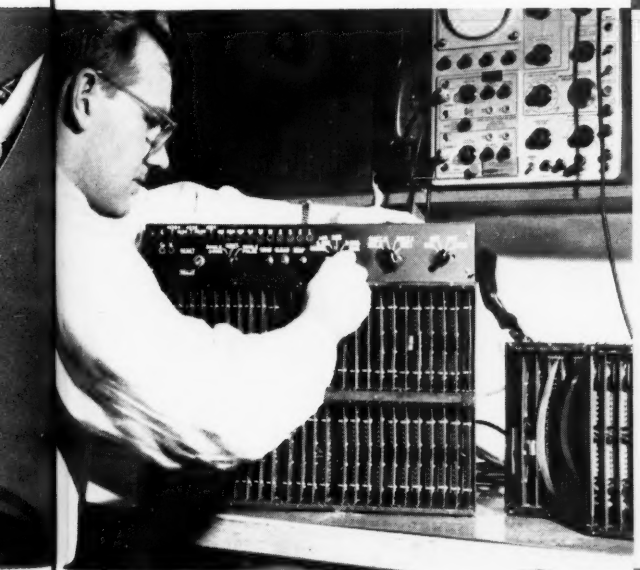
NEW linear integrating accelerometers weigh only 1½ lb., measure exact velocity of aircraft or missile in any direction. New sensing mechanism moves in straight line, eliminating errors inherent in previous types.

AIR ARMAMENT DIVISION

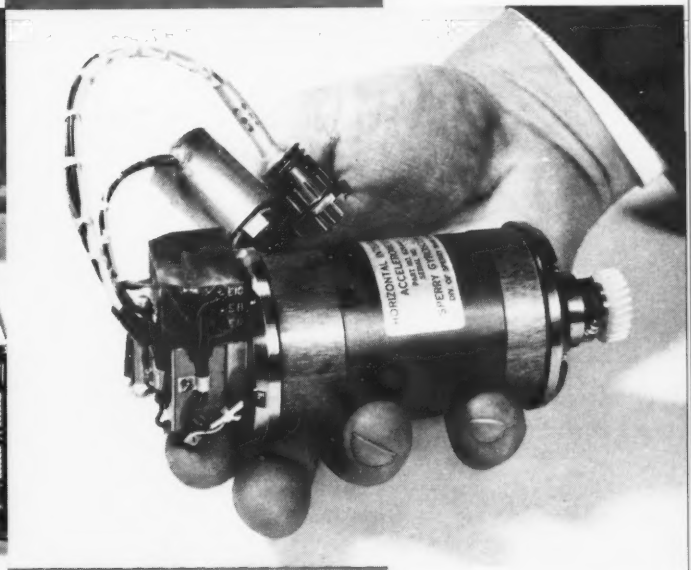
SPERRY GYROSCOPE COMPANY

Great Neck, New York

DIVISION OF SPERRY RAND CORPORATION



ENGINEER TESTS new airborne digital computer designed by Sperry. Computer accepts data from stable platform's gyros and accelerometers, gives instructions for automatic corrections in flight path. Closely related operator displays permit inflight monitoring and control.



ULTRA-SENSITIVE floated gyroscope minimizes random drift, assuring high performance for inertial system over long periods. These production gyros withstand shock and vibration many times the force of gravity.

ARS news

Detroit Plays Host to ARS Fall Meeting Sept. 15–18

THE ARS Fall Meeting this year focuses attention for the first time on the production end of astronautics. Scheduled for Detroit, home of one of the country's largest missile manufacturing facilities, it promises a full-scale look, for the first time anywhere, at how our missiles are being designed, engineered, planned for production, manufactured and inspected, as well as how they're tested and handled in the field.

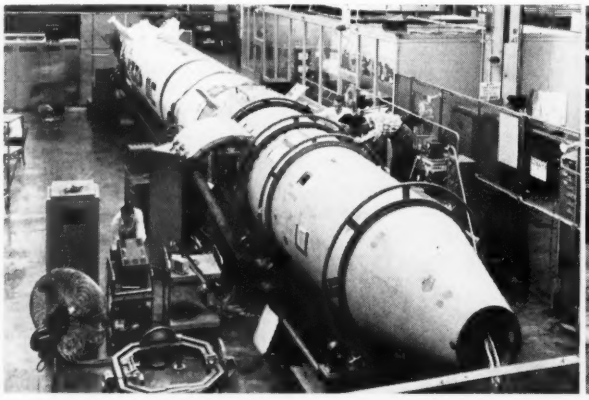
The meeting, to be held in Detroit's Hotel Statler Sept. 15–18, will be highlighted by eight technical sessions, covering such subjects as small and large missile manufacturing, long-range missile components, missile logistics and operations, and controls for supersonic air-breathing engines. At classified sessions, two of today's hottest topics—monopropellants and nonpropulsive power systems—will come under close scrutiny.

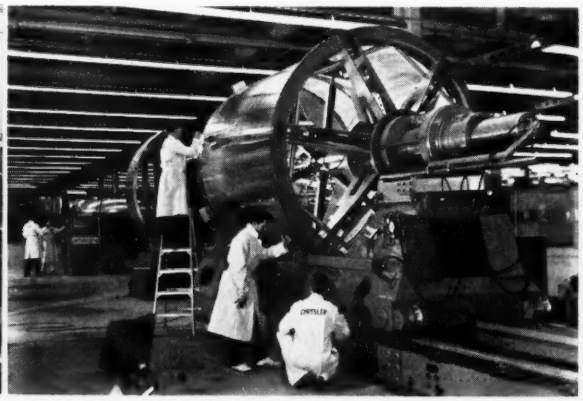
One outstanding session will be devoted to a panel discussion on "The Impact of Space Flight on Industry." Harlan Hatcher, president of the Univ. of Michigan, will chair the six-man panel, with Wilbur Nelson, head of the university's aeronautical engineering department, as vice-chairman.

The excellent program has been arranged by the meeting committee, headed by Fred Klemach of Vickers, Inc., general chairman; Charles W. Tait, Wyandotte Chemical Co., Detroit Section president; and Lovell Lawrence of Chrysler Missile Div., in cooperation with the ARS national program committee, headed by Howard Seifert of Space Technology Labs, and the ARS technical committee chairmen.

Lt. Gen. Arthur G. Trudeau, Army R&D Chief, will be the banquet speaker, while George Valley, AF Chief Scientist, will be the luncheon

Detroit's Statler Hotel, scene of the Fall Meeting.





Field trip will take ARS members through Chrysler Missile Div. facilities like the final Redstone checkout area (left) and Jupiter ballistic shell area (right).

BANQUET SPEAKER

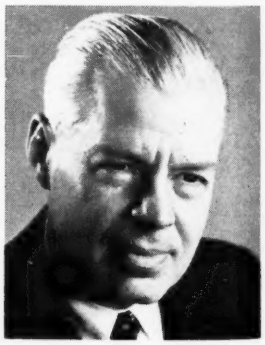
Lt. Gen. Arthur G. Trudeau
Army R&D Chief

LUNCHEON SPEAKERS

George Valley
AF Chief Scientist

Maj. Gen. John H. Hinrichs
Army Chief of Ordnance

PANEL CHAIRMAN



Harlan Hatcher
President, Univ. of Michigan

speaker on Tuesday, Sept. 17, and Maj. Gen. John H. Hinrichs, Army Chief of Ordnance, will be the luncheon speaker the following day.

The meeting will get underway Monday evening, Sept. 15, with a reception sponsored by the following Detroit Region ARS corporate members: Aeroquip Corp., Burroughs Corp., Chrysler Corp., Continental Aviation and Engineering Corp., Dearborn Machinery Movers Co., Electro Mechanical Products Co., Ford Motor Co., General Motors Corp. Research Staff, Kelsey-Hayes Co., Koebel Diamond Tool Co., George L. Nankervis Co., Vickers and Wyandotte Chemical Corp.

Chrysler Missile Div. will be the host at a reception prior to the banquet on Wednesday evening, Sept. 17.

Gov. G. Mennen Williams of Michigan will deliver a brief welcoming address at the banquet.

Another highlight of the meeting, expected to draw an attendance of 1000, will be a field trip to the Chrysler Missile Div. facilities on Thursday, Sept. 18. A classified (confidential) tour of the Jupiter ballistic shell area, Redstone production area, missile labs section, material and prototype, electrical and guidance and control, structures and mechanics labs has been arranged for those making the trip.

An extra at the meeting will be a special exhibit of astronautical and missile components and equipment made by local contractors, arranged by the Detroit Section. Among those scheduled to exhibit are Chrysler, Fruehauf Trailer, Vickers, Continental Aviation, Kelsey-Hayes, Kay-Don Engineering Co., Brooks and Perkins, Koebel, Vinco Corp., Wyandotte and Tiby Engineering Products.

The complete program, along with ARS preprint numbers for all technical papers, follows:

Monday, September 15

6:00 p.m. **Grand Ballroom**

FALL MEETING RECEPTION

Tuesday, September 16

9:30 a.m. **Grand Ballroom**

SMALL MISSILE PRODUCTION DEVELOPMENTS

Chairman: John W. Black, Plant Manager, Hughes Aircraft Co., Tucson, Ariz.

Vice-Chairman: Louis L. Reasor, Works Manager, Hughes Aircraft Co., Tucson, Ariz.

✦ Coordinated Industry-Government Acceptance Inspection Plan, William H. Rombach, Chief Quality Control Engineer, Philco Corp., Philadelphia, Pa., and Capt. L. C. Baldauf, Quality Control, Bureau of Ordnance, USN. (652-58)

✦ Effective Control of Change Orders and Missile Production, D. M. Rush, Manager

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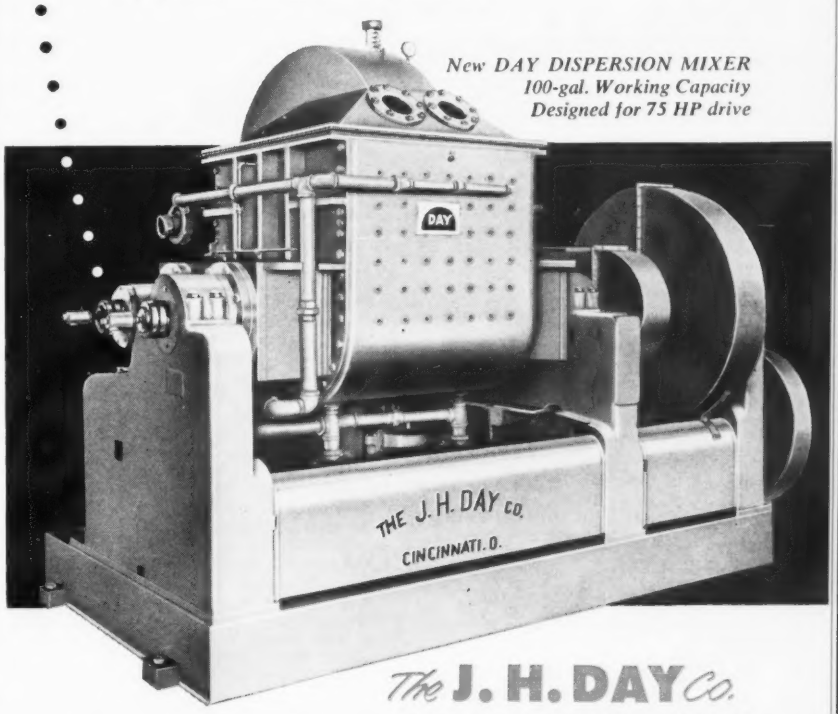

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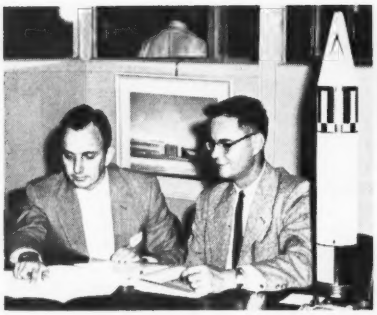

Planning the meeting. Left, general chairman Fred Klemach of Vickers and Charles W. Tait of Wyandotte, Detroit Section president. At right, seated left to right, are Klemach, and Charles Gibson and Ed Nielsen of Chrysler, and, standing in same order, David Buell and Charles W. Williams of Chrysler and Tait.

of Production Control, Raytheon Mfg. Co., Lowell, Mass. (653-58)

✦ Manufacturing Integral Electronics in Small Missiles, G. E. Sylvester, Asst. Chief Engineer, Product Engineering, Convair, Div. of General Dynamics Corp., Pomona, Calif. (654-58)

✦ Test Equipment Design and Utilization for Small Missiles, William W. Caskey Jr., Manager of Engineering, Hughes Aircraft Co., Tucson, Ariz. (655-58)

9:30 a.m. **Michigan Room**

LONG-RANGE MISSILE COMPONENTS

Chairman: Lew Scheuer, Ford Instrument Co., Long Island City, N.Y.

Vice-Chairman: E. N. Bowen, General Motors Research Staff, Detroit, Mich.

✦ An Approach to System Performance Prediction—Reliability as an Evaluating Factor, Robert E. Roberson, Staff Specialist, Autonetics Div., North American Aviation, Downey, Calif. (656-58)

✦ Hydraulic Missile Components, Arthur B. Billet Sr., Staff Engr., Vickers, Inc., Detroit, Mich. (657-58)

✦ A Two Degree of Freedom Gyro and Its Application, Charles J. Mundo and Sydney Osband, Arma Div., American Bosch Arma Corp., Garden City, N.Y. (658-58)

✦ The Floated Gyroscope—A "Canned" Signpost for Space Flight on Earth or in Outer Space, William G. Denhard, Asst. Director, MIT Instrumentation Lab, Cambridge, Mass. (659-58)

✦ Characteristics of the Air Bearing Gyroscope, H. C. Rothe, Chief of Gyro and Stabilizer Branch, Army Ballistic Missile Agency, Huntsville, Ala. (660-58)

12:00 Noon **Grand Ballroom**

LUNCHEON

Toastmater: Frank Forster, President, Vickers, Inc.

Speaker: George E. Valley, Chief Scientist, Department of the Air Force

2:30 p.m. **Grand Ballroom**

FORUM: IMPACT OF SPACE FLIGHT ON INDUSTRY

Chairman: Harlan H. Hatcher, President, Univ. of Mighican

Vice-Chairman: Wilbur Nelson, Dept. of Aeronautical Engnrg., Univ. of Michigan

PANEL MEMBERS

Willis Hawkins, Gen. Mgr., Lockheed Missile Systems Div., Sunnyvale, Calif.; Brig. Gen. Homer Boushey, ARDC; K. J. Bossart, Tech. Dir., Convair-Astronautics, San Diego, Calif.; Richard Cesaro, ARPA, Washington, D.C.; George E. Valley, Chief Scientist, Dept. of the Air Force, Washington, D.C.; George Trimble, Vice-President, The Martin Co., Baltimore, Md.

2:30 p.m. **Michigan Room**

CONTROLS FOR SUPERSONIC AIR-BREATHING ENGINES

Chairman: Brooks T. Morris, Executive Engineer, Powerplants, Marquardt Aircraft Co., Van Nuys, Calif.

Vice-Chairman: Joseph Rutkowski, Wayne State Univ., Detroit, Mich.

✦ Ramjet Fuel Controls, Francis A. Heinz, Bendix Products Division, Bendix Aviation Corp., Mishawaka, Ind. (661-58)

✦ An Introduction to the Control of Ramjet Engines, W. H. Henley, Marquardt Aircraft Co., Van Nuys, Calif. (662-58)

✦ Ramjet Speed Control Application to Integrated Missile System, Hugh Davis & Kenneth D. Rice, Boeing Airplane Co., Pilotless Aircraft Div., Seattle, Wash. (663-58)

✦ Control System Requirements for Supersonic Air-breathing Engines, H. Richardson, Curtiss-Wright Corp., Wright Aeronautical Division, Wood Ridge, N.J. (673-58)

Wednesday, September 17

9:30 a.m. **Michigan Room**

MONOPROPELLANTS (Confidential)

Sponsored by Detroit Ordnance District

Chairman: Charles W. Tait, Wyandotte Chemicals Corp., Wyandotte, Mich.

Vice-Chairman: John D. Clark, Naval Air Rocket Test Station, Lake Denmark, Dover, N.J.

✦ Recent Monopropellant Work at NARTS, Michael E. Walsh, Head, Physical and Synthetic Chemistry Branch, Naval Air Rocket Test Station, Lake Denmark, Dover, N.J.

✦ High-Energy Monopropellants, J. E. Mahan, et al., Manager, Chemicals and Rockets Branch, Phillips Petroleum Co., Bartlesville, Okla.

✦ The Evaluation of High-Energy Liquid Monopropellants, William A. Cuddy, Section Head, Combustion, Liquid Propellants, Wyandotte Chemicals Corp., Wyandotte, Mich.

✦ High-Energy Monopropellants, Jack R. Gould, Head, Organic Chemicals Section, Stauffer Chemical Co., Chauncey, N.Y.

9:30 a.m. **Grand Ballroom**

BALLISTIC MISSILE MANUFACTURING —JUPITER AND REDSTONE

Chairman: Charles W. Williams, Manager-Mfg., Chrysler Missile Div., Detroit, Mich.

Vice-Chairman: J. F. Zerbey, Plant Engineer, Chrysler Missile Div., Detroit, Mich.

✦ Rocket Engine, Walter Studhalter, Redstone Program Engineer, Rocketdyne Div. of North American Aviation, Inc., Canoga Park, Calif. (664-58)

✦ Guidance & Control Components, John Young, Manager-Mfg. Engineering, Ford Instrument Co., Div. of Sperry Rand Corp., Long Island City, N.Y. (665-58)

✦ Electrical Components, J. W. Albright, Manager, Electrical Production Engineering Section, Chrysler Missile Div., Detroit, Mich. (666-58)

✦ Mechanical Components and Final Assembly, J. S. Sheldon, General Superintendent, Assembly and Mech. Fabrication, Chrysler Missile Div., Detroit, Mich. (667-58)

✦ Missile Systems Acceptance Inspection, Donald K. Meikle, Dept. Head-Missile Final Acceptance Testing, Chrysler Missile Div., Detroit, Mich. (668-58)

12:00 Noon **Grand Ballroom**

LUNCHEON

Toastmaster: Carl Bachle, Vice-President, Continental Aviation & Engineering Corp.

Speaker: Major General J. H. Hinrichs, Chief of Ordnance, Department of the Army

2:30 p.m. **Michigan Room**

NON-PROPULSIVE POWER FOR MISSILES (Secret)

Sponsored by Detroit Ordnance District

Chairman: Arthur B. Ash, Sundstrand Turbo, A Div. of Sundstrand Machine Tool Co., Pacoima, Calif.

Vice-Chairman: F. Moncher, Vickers, Inc., Detroit, Mich.

✦ Impact of Space Age on Secondary Power Requirements, Rear Adm. Thomas A. Ahroon, Asst. Chief for Plans, Bureau of Ordnance, Washington, D.C.

✦ Space Vehicle Power, Brig. Gen. Ralph L. Wassell, Asst. Deputy Commander for R&D ARDC, Andrews AFB, Washington, D.C.

✦ Trends in Military Requirements for Secondary Power Projected for the Next Ten Years, Brig. Gen. Earle F. Cook, Chief, R&D, Office of Chief Signal Officer, Dept. of Army

2:30 p.m. **Grand Ballroom**

MISSILE LOGISTICS AND OPERATIONS

Chairman: Maj. Gen. John B. Medaris, Commander, Army Ordnance Missile Command, Redstone Arsenal, Ala.

Vice Chairman: Col. Charles G. Patterson, Assistant Chief of Staff for Military Applications & Training, Army Ordnance Missile Command, Redstone Arsenal, Ala.

✦ Maintenance Management—Operational Readiness Plan for the Redstone Missile System—"The MOR Plan," Lt. Col. Brian O. Montgomery, Chief, Field Support Div., Army Ballistic Missile Agency, Redstone Arsenal, Ala. (669-58)

✦ The Application of Universal Test Equipment to the Readiness and Reliability of Missile Systems, Lt. Col. Frank E. Napper, Chief, Field Service Div., Army Rocket &

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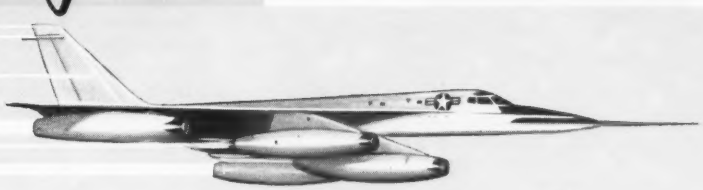

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Guided Missile Agency, Redstone Arsenal, Ala. (670-58)

✦ Air Force Logistics System for Ballistic Missiles, Col. Henry G. MacDonald, USAF, Chief, Air Force Jupiter Liaison Office, Army Ballistic Missile Agency, Redstone Arsenal, Ala. (671-58)

✦ Education and Training of the Field Engineer, Robert C. Terbeck, Asst. Chief Engr., Field Support Branch, Chrysler Corporation, Detroit, Mich. (672-58)

6:00 p.m. **Michigan Room**

RECEPTION

7:00 p.m. **Grand Ballroom**

BANQUET

Toastmaster: Thomas Morrow, Vice-President, Chrysler Corporation

Speaker: Lieut. General Arthur G. Trudeau, Chief of Research and Development, Department of the Army

Thursday, September 18

8:30 a.m.

FIELD TRIP (Confidential)

Tour of Chrysler Corp. Missile Div. facilities, including Jupiter ballistic shell and Redstone production areas, and missile laboratories section, material and prototype, electrical and guidance and control, structures and mechanics laboratories.

ARS Meeting Schedule For Next Year Listed

Following is a complete listing of ARS national meetings for 1959:

March 23–25—Spring Meeting, Daytona Beach, Fla.

May 25–27—National Telemetering Conference, co-sponsored by ARS, AIEE, IAS and ISA, Denver, Colo.

June 8–11—Semi-Annual Meeting, San Diego, Calif.

Aug. 24–26—Gas Dynamics Symposium, Northwestern Univ., Evanston, Ill.

Nov. 16–20—14th Annual Meeting, Washington, D.C.

Programs and meeting information will be available one month in advance of each meeting from ARS headquarters.

Irvine Named

Thomas Irvine of the Univ. of Minnesota has been appointed ARS representative to the North American Committee of the Second International Heat Transfer Conference, to be held in 1961.

U.S. Space Flight Program Suffers Tragic Loss

The tragic death of Capt. Iven C. Kincheloe Jr. represents a tremendous loss—to his family, to the country, to our man-in-space effort. Unfortunately, his death is not the first to mark this nation's space flight effort, nor the last. However, as the pilot selected to make the first test of the full capabilities of the X-15 for the Air Force, Capt. Kincheloe, perhaps more than any other individual, symbolized our hopes and aspirations in this area.

Capt. Kincheloe's death points up the many dangers our first space men will face. Even more important, it serves to demonstrate how quickly the lives of these men, with the unusual combination of physical and mental aptitudes, background, interest and initiative, experience and training necessary for space flight missions, can be snuffed out. The tremendous loss of such highly specialized human resources cannot be overestimated.

I had the good fortune to know Capt. Kincheloe quite well, and spoke to him just a day or two before his death. A loyal and enthusiastic ARS member for some years, he was vice-president (and president-elect) of the Antelope Valley Section at the time of his death, and when I spoke to him was filled with plans for the future.

A remark made by Capt. Kincheloe several months ago perhaps summed up his feelings about man and space. Dressed in his full-pressure suit and holding his infant son in his arms, he said: "You know, I may not get to the moon. . . But even if I don't, my son surely will."

He will be sorely missed by us all.

—George P. Sutton

Final Approval Near for Standard Letter Symbols

A proposed list of American Standard Letter Symbols for Rocket Propulsion (ASA Y10) has been completed by Subcommittee 17 of the American Standards Assn. Sectional Committee on Letter Symbols and forwarded to all committee members for letter ballot vote.

The proposal was distributed to industry for comment through the medium of JET PROPULSION (November, 1955 issue, pages 634–645) and reprints from the magazine. Comments received as a result of its publication were carefully considered by the subcommittee and formed the basis for the April, 1958, redraft which was voted on.

Six More Companies Become ARS Members

Six more companies have become corporate members of the AMERICAN ROCKET SOCIETY. The companies, their areas of activity and those named to represent them in Society activities are:

Avco Mfg. Corp. Research and Advanced Development Division, Lawrence, Mass., engaged in the development and fabrication of re-entry vehicles, re-entry studies, high-temperature materials research, environmental testing and flight simulation, and communication and data handling research and development. Representing the company in ARS are: Dorothy M. Simon, technical staff assistant to the president; Jack A. Kyger, project director; Abraham Kahane, project engineer, advanced design programs; Murray E. Malin, chief, physics sections; and J. R. McLeod, public relations manager.

Beaver Precision Products Inc., Clawson, Mich., active in manufacturing ball screws, splines and way cartridges used in missile control systems, plotting and tracing boards, radar controls, fuel metering, etc. Named to represent the company in ARS are: Roy L. Blanchard, president; John A. Hope, vice-president, sales; Richard E. Sears, vice-president, engineering; Walter H. Morris, chief product engineer; and William G. Newman, chief sales engineer.

Burroughs Corp., Detroit, prime contractor for ground guidance computer in AF Atlas ICBM, responsible for research and development of prelaunch data computer for Regulus II inertial guidance system, and prime contractor for airborne bomb-rocket missile control and navigation computers. Named to represent the com-

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N_2O_4 Oxidant for liquid rocket propellants

Molecular weight	92.02
Boiling Point	21°C
Freezing Point	−11.3°C
Latent Heat of Vaporization	99 cal/gm @ 21°C
Critical Temp.	158°C
Critical Pressure	99 atm
Specific Heat of Liquid	0.36 cal/gm −10 to 20°C
Density of Liquid	1.45 gm/ml at 20°C
Density of Gas	3.3 gm/liter 21°C, at 1 atm
Vapor Pressure	2 atm at 35°C

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pany in ARS are: Paul S. Mirabito, general manager, defense contracts organization; Jack C. Lindley, defense sales manager; Harry B. Rottiers, director, defense contracts; Richard J. Egger, director, defense sales planning; and A. F. France, contracts manager, Atlas program.

Clifton Precision Products Co., Philadelphia, Pa., active in the field of guidance and control; manufacturers of precision electromechanical assemblies. Representing the company in ARS are: Thomas W. Shoop, vice-president, sales; Arnold E. Hayes, vice-president, systems engineering; H. Thomas Larkins, eastern sales manager; Edwin J. Gately, midwest sales manager; and Vincent Mammarelli, chief engineer.

The Kaman Aircraft Corp., Bloomfield, Conn., manufacturer of helicopters for Navy and AF, and of subcontract parts for missile and aircraft manufacturers. Active in research and development, VTOL aircraft, robots, electronics and atomics. Representing the company in ARS are: Charles H. Kaman, president; E. J. Odlum, senior vice-president; J. O. Emmerson, vice-president and chief engineer; W. N. Stone, assistant chief engineer; and R. A. Strieby, chief, military operations research.

National Company, Inc., Malden, Mass., active in design, development and manufacturing of electronic communications, navigation and guidance systems; receivers, transmitters, test equipment, atomic frequency standards (atomichron) and secure communications. Representing the company in ARS are: H. C. Guterman, chairman of the board; J. H. Quick, president; H. Kafafian, missiles; Vice Adm. M. L. Royar (USN-Ret.), director; and E. F. Grant, vice-president, engineering.

SECTIONS

Chicago: New officers of the section are as follows: Stephen J. Fraenkel, president; Andrew A. Affrunti, vice-president; Ben C. Harrison, secretary; and George R. Herman, treasurer.

Columbus: The section's annual dinner meeting at the Southern Hotel drew a record attendance of 129 members and guests, among whom were B. D. Thomas, president of Battelle Memorial Institute and G. L. Von Eschen, chairman of the Aeronautical Engineering Dept. of Ohio State University.

After a pleasant meal, Arthur Greshemer, program director, introduced the guest speaker, Walter Dornberger of Bell Aircraft Corp., who spoke on the subject, "Have We Lost Technological Superiority?" Dr. Dornberger's talk and an ensuing question-and-answer period were tape recorded for radio presentation the first Sunday in August.

—Dean L. Pendleton

Holloman: The regular monthly meeting was held July 22 in the ballroom of the Officers' Club at Holloman AFB. President Millsaps being in Washington, D.C., the after-dinner portion of the meeting was opened by vice-president Gerhard W. Braun, who introduced Bernard E. Oldfield, director of the Hughes Aircraft Test Program at the Air Force Missile Development Center, the new Center Commander, Brig. Gen. Daniel E. Hooks, and the guest speaker for the evening, Samuel Herrick, distinguished astronomer at UCLA, consultant to the Rand Corp., and pioneer and world authority in problems of space travel.

Professor Herrick spoke primarily on the solar system and problems of interplanetary navigation. The first part of his presentation included color slides of some paintings by Chesley Bonestell, who has become well-known for depicting the scenes which the space traveler might expect to see. An interesting slide showed that the space traveler visiting the moon would find it illuminated by earth light, or solar light reflected from the earth, about 100 times as strong as moonlight is on the earth.

Dr. Herrick discussed the inhospitable nature of the surface of some of the other planets, and pointed out that since Mercury keeps the same side facing the sun at all times it has one blistering hot side and one very cold side. He also invited attention to the fact that modern astronomers believe that the atmosphere of Saturn is composed largely of heavy gases such as ammonia and methane and would be entirely unsuited to life as we know it. He pointed out, possibly to please the ambitious youngsters in the audience who are dreaming of interplanetary travel, that there is a possibility that the larger moons of the outer planets may have sufficient oxy-

On the calendar

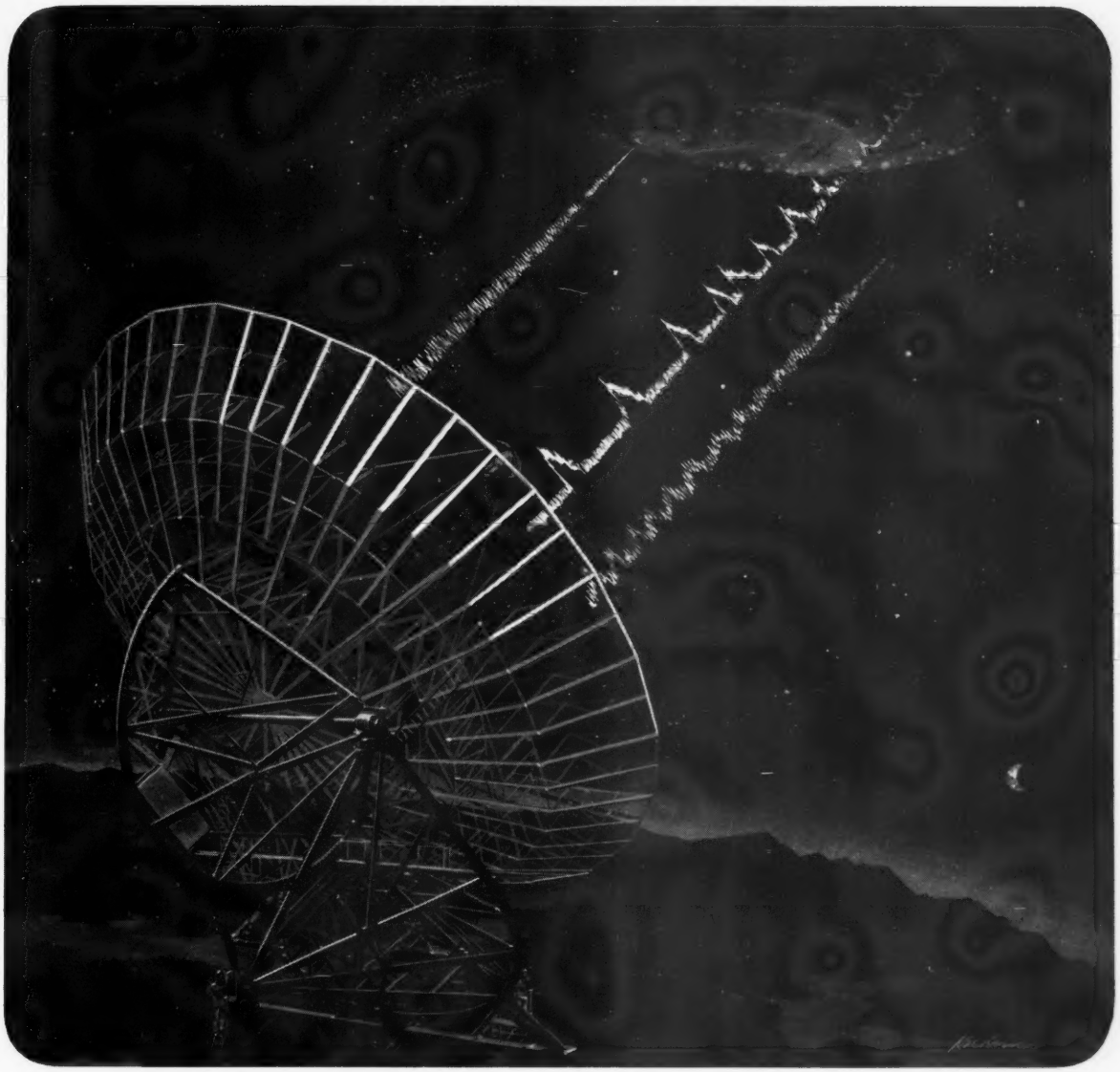
1958

Sept. 1–6	1958 Farnborough Flying Display and Exhibition, Farnborough, England.
Sept. 3–5	1958 Cryogenic Engineering Conference, MIT, Cambridge, Mass.
Sept. 8–13	First International Congress of Aeronautical Sciences, sponsored by IAS, Madrid, Spain.
Sept. 15–18	**ARS Fall Meeting, Hotel Statler, Detroit, Mich.**
Sept. 22–24	IRE National Symposium on Telemetering, the Americana Hotel, Bal Harbour, Miami Beach, Fla.
Oct. 13–15	National Electronics Conference, sponsored by IRE, AIEE, EIA, Hotel Sherman, Chicago.
Oct. 14–16	**ARS New Mexico-West Texas Section and American Meteorological Society High Atmosphere Conference, El Paso, Tex.**
Oct. 23–25	International Symposium on Rockets and Astronautics, sponsored by Deutsche Gesellschaft fur Raketentechnik und Raumfahrt, Essen, West Germany.
Oct. 23–25	National Society of Professional Engineers Fall Meeting, St. Francis Hotel, San Francisco.
Nov. 6–7	Nationalist Specialist Meeting on Dynamics and Aeroelasticity, sponsored by IAS Texas Section, Texas Hotel, Ft. Worth, Tex.
Nov. 10–12	AF School of Aviation Medicine-Southwest Research Institute Space Symposium, Hilton Hotel, San Antonio, Tex.
Nov. 17–21	**ARS 13th Annual Meeting, Hotel Statler, New York, N.Y.**
Dec. 17	Wright Brothers Lecture, sponsored by IAS, Natural History Bldg., Smithsonian Institution, Washington, D.C.

1959

Jan. 26–29	27th Annual IAS Meeting, Sheraton-Astor Hotel, N.Y.C.
Feb. 3–5	14th Annual Technical and Management Conference of the Reinforced Plastics Div. of The Society of the Plastics Industry, Edgewater Beach Hotel, Chicago.
Mar. 19–20	Flight Propulsion Meeting, sponsored by IAS, Hotel Carter, Cleveland, Ohio.
March 23–25	**ARS Spring Meeting, Daytona Beach, Fla.**
April 5–10	Fifth Nuclear Congress of Engineers Joint Council, Cleveland Auditorium, Ohio.
May 25–27	**National Telemetering Conference, co-sponsored by ARS, AIEE, IAS, and ISA, Denver, Colo.**
June 8–11	**ARS Semi-Annual Meeting, San Diego, Calif.**
Aug. 24–26	**ARS Gas Dynamics Symposium, Northwestern Univ., Evanston, Ill.**
Nov. 16–20	**ARS 14th Annual Meeting, Washington, D.C.**

IMPORTANT DEVELOPMENTS AT JPL



PIONEERS IN EARTH-SPACE COMMUNICATIONS

The exploration of outer space will take a new step forward with the completion of the new giant radio antenna being installed by JPL near Barstow, California. This huge "dish," 85 ft. in diameter, will enable the Laboratory scientists to probe still farther into space problems.

Information thus obtained and combined with lessons still being learned from the successful Army "Explorer" satellites, will provide invaluable basic data for the development of communication systems to serve space exploration programs. Long range communication will begin as a one-way link from space to earth, developing later into tracking and communicating with lunar vehicles at far greater ranges.

This activity will be part of a great research and development program to be operated jointly by JPL and the United States Army Missile Command.

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gen in their atmosphere to be more attractive landing points than the surface of the planets themselves.

In the latter part of his discussion, Dr. Herrick discussed the historical background of astronomy. He described Kepler's laws and the conservation of angular momentum; Galileo's work; Newton's derivation of universal gravitation; the equatorial bulge of the earth and other sources of perturbation which influence satellite orbits; the fundamental equations of satellite orbits; and velocity increments needed to go from a circular orbit to other orbits and to escape velocity along parabolic and hyperbolic paths.

He pointed out the great difference between the feasibility studies which have been made in countless numbers in recent years and the actual detailed calculation needed to land on any other celestial body after departing from the Earth.

He concluded his lecture with a beautiful slide of a photograph of Venus and the Moon made from, as he put it, the only planet that he feels sure is habitable, Mother Earth.

—Lt. Col. Harry L. Gephart

San Diego: Newly elected officers are Hans Friedrich, Convair-Astronautics, president; William F. Radcliffe, Convair-Astronautics, vice-president; Jack Clothier, Ryan Aeronautical, treasurer; and Dan Heald, Convair-Astronautics, secretary. New members of the executive board of directors are R. C. Sebold, vice-president of engineering at Convair; Krafft Ehricke, Convair-Astronautics, and William H. Dorrance, Convair Scientific Research Dept.

Southern Ohio: A large group of members, friends and students at the July meeting, held in the auditorium of GE's Evandale Plant, heard guest speaker Edwin P. Hiatt, acting chief of the biophysics branch of WADC's Aero Medical Laboratory, discuss "Human Problems of the Space Frontier."

Dr. Hiatt, directly involved with basic research being conducted on space physiology, noted that the subject of space flight has been much distorted by science-fiction and other popular media writers, and spoke with the intention of clarifying what specifically has been done to date in his field, called "human factors."

He mentioned that progress has been made in problems of artificial-atmosphere control and the tolerance of humans to artificial atmospheres; that nutrition has been studied, with little success as yet in the reprocessing of waste; and that toxic factors of radiation, the effect of weightlessness, emergency escape from a space ship, and continuous communication with space travelers are just beginning to see concentrated investigation.

Dr. Hiatt thinks that the most critical aspect of space flight for man is the psychological one. Men who are "tigers" crack up under prolonged isolation in ground-test space cabins, he noted, while "rabbits" seem to weather isolation satisfactorily. The psychological significance of isolation, now just coming under study, will not be fully known, he believes, until man takes to space.

—I. E. Kantor

St. Louis: The June 25 meeting, held in the auditorium of McDonnell Aircraft Corp., was attended by a capacity audience, who heard the speaker of the evening, Robert E. Roberson, chief of astronautical sciences in the Autonetics Div. of North American Aviation, Inc., discuss "Attitude Control of Satellite Vehicles" lucidly and with humor.

P. W. Godfrey, section president, announced tentative plans for a short series of lectures on rocket fundamentals to be presented in the fall with the cooperation of Washington University. These lectures would be aimed at high school teachers.

—James N. Holsen

Valley Forge: The section held its charter meeting June 5 at the Conestoga, High School, Berwyn, Pa. Mem-

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Andrew G. Haley, General Counsel

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(Terms expire on dates indicated)

Krafft Ehricke, 1959
S. K. Hoffman, 1958
Simon Ramo, 1960
H. W. Ritchey, 1959
H. S. Seifert, 1958
K. R. Stehling, 1958
Martin Summerfield, 1959
Wernher von Braun, 1960
Maurice J. Zucrow, 1960

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Brooks T. Morris, Ramjet
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John Sloop, Propellants and Combustion
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Simon Ramo, Publications
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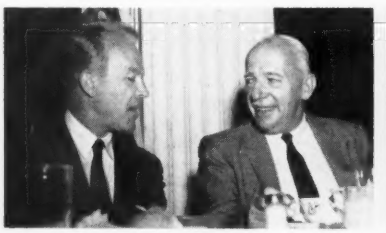
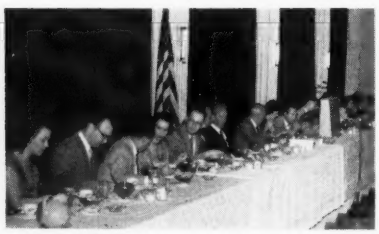
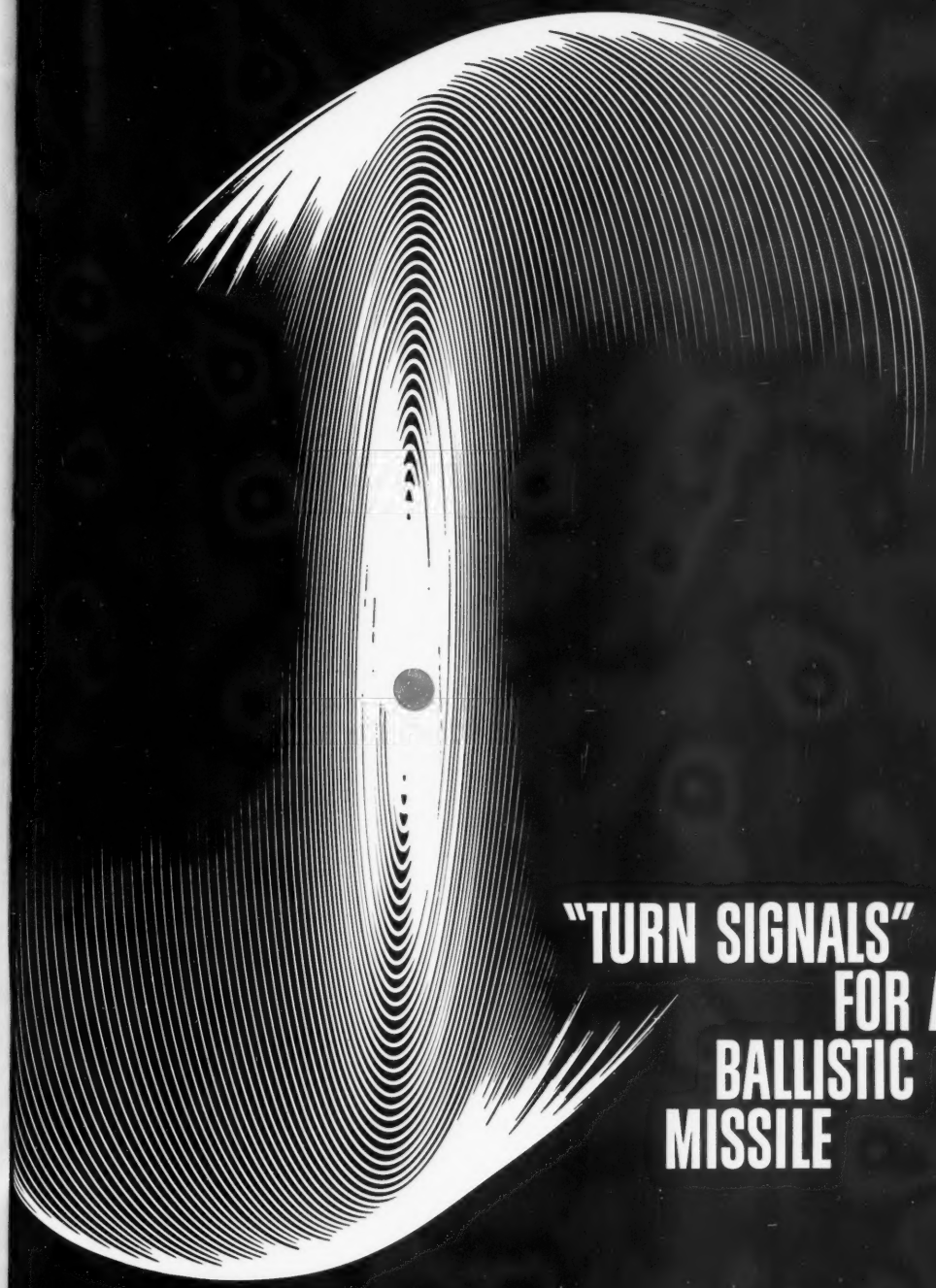
Martin Summerfield, Policy

At ARS Columbus Section's Annual Dinner Meeting

At left, guest speaker Walter Dornberger (right) of Bell Aircraft chats with Charles J. Gallant, vice-president of North American Aviation and general manager of NAA's Columbus Div., at Columbus Section's annual dinner meeting. At right, the head table.







"TURN SIGNALS" FOR A BALLISTIC MISSILE

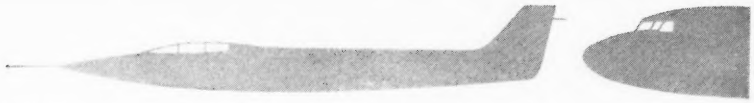
BURROUGHS ELECTRONIC COMPUTER "MASTERMINDS" THE ATLAS INTERCONTINENTAL BALLISTIC MISSILE

Steering the 250-mile-per-minute Atlas into the precise trajectory required for the missile to accurately strike its target 5,500 miles away, calls for incredibly close computation. And that's where Burroughs comes in—with an electronic computer specially designed to receive complex information, compare it with the pre-calculated direction, and signal the missile necessary changes to set it unerringly on its course.

Important contracts are not new to Burroughs Corporation with its 70 years of demonstrated competence. But it is the recent defense projects that serve best to underscore Burroughs' breadth and complete capability, from research through mass production to actual field installation and service. Burroughs Corporation, 6071 Second Avenue, Detroit 32, Michigan.

BURROUGHS CORPORATION

THE FOREMOST NAME IN COMPUTATION



CEC's new potentiometer pressure pickups

CEC's new potentiometer pressure pickups

CEC's new ... eter pressure pickups

airborne applications have been carefully considered in the design of Consolidated's pot pressure pickups. Minimum size and weight... mounting convenience through an integral flange base and parallel fittings... superior resistance to shock and vibration... are immediately apparent advantages. In both pickups, pressure fluid remains external to the wiper system, precluding potentiometer contamination by the measured media. Operating temperature range is −65°F to 200°F.

LOW-PRESSURE TYPE 4-380 is designed for absolute, gage, and differential pressure measurements of non-corrosive fluids in ranges up to 100 psi. Flexure pivot assembly gives minimum hysteresis (0.6%), friction of less than 1%, and zero backlash. Linearity is ±1%. Weight, only 8 oz.

HIGH-PRESSURE TYPE 4-381 is offered in differential and gage models from 600 to 5,000 psi, and absolute models from 600 to 1500 psi. Design features solid construction of 303 stainless steel, fail-safe case that takes 10,000 psi, vibration resistance to more than 25 g's in a small 2″ x 2″ x 1⅛″ package.

For complete information, contact your nearest CEC sales and service office, or write for Bulletins CEC 1604-X8 and 1611-X2.

Transducer Division CEC

FOR EMPLOYMENT OPPORTUNITIES in this progressive company, write Director of Personnel.

Consolidated Electrodynamics

300 North Sierra Madre Villa, Pasadena, California

RECOGNIZED LEADER IN GALVANOMETERS—TELEMETRY, PRESSURE AND VIBRATION INSTRUMENTATION

bers and guests saw the charter presented by Kurt Stehling, head of NRL's Rocket Section and member of the ARS board, and heard him speak on "Advanced Considerations of Space Flight Propulsion." William L. Doyle, president of the section, introduced its board of directors and briefly described the aims of the section at the meeting.

Wichita: The section held its summer meeting for members and their wives on the evening of June 27 at Beech Aircraft Corp. Highlight of the evening was a film featuring Wernher Von Braun discussing problems of launching a manned, recoverable satellite.

CORPORATE MEMBERS

Lockheed Missile Systems Div. will build a $7 million main plant addition at Sunnyvale, Calif., where development work on AF satellites will be centered. The 346,000-sq ft building is slated for completion in the fall of 1959. The division's Space Communications Lab has been almost doubled in size by the addition of an 8000-sq ft unit.

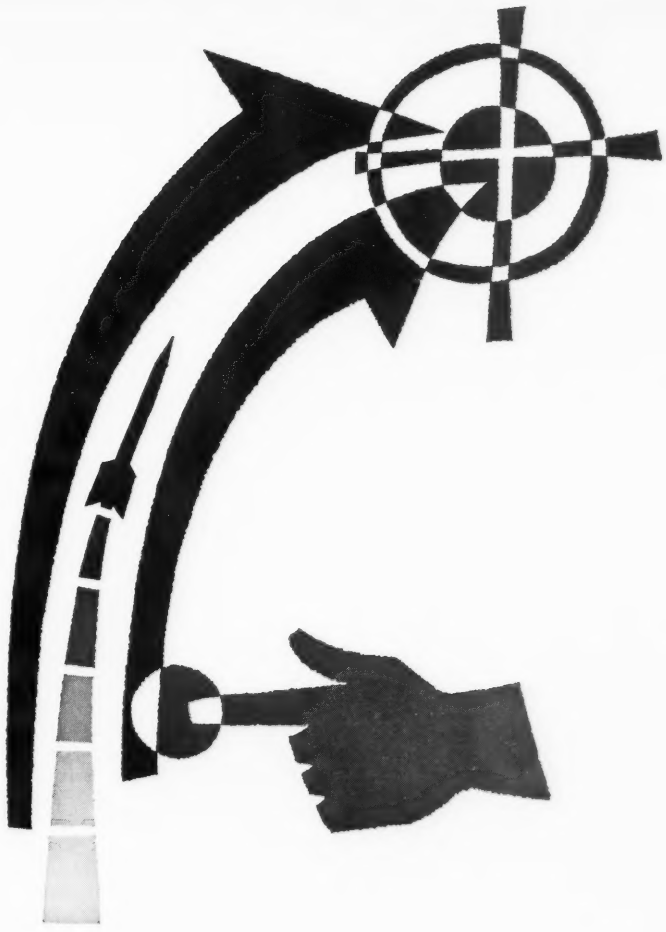
Recently completed expanded research facilities of **Wyandotte Chemicals Research and Engineering Div.** will enable the company to take on a wide range of corporate and DOD research projects dealing with high pressures and temperatures, and toxic materials.

Controlling interest in **Grand Central Rocket Co.** has been transferred to Petro-Tex Chemical Corp., Houston, Tex., by Tennessee Gas Transmission Co. Petro-Tex is jointly owned by TGT and Food Machinery and Chemical Corp.

Republic Aviation has announced a $35 million R&D program in astronautics, covering space vehicles, missiles and missile systems, and "sophisticated" aircraft. The outlay will include $14 million for a new R&D center at the company's main plant in Farmingdale, L.I., which will house nine separate labs. Ground for the new center will be broken next month, with the labs expected to be in operation late in 1959.

ICBM/IRBM Training Bases

Facilities designed to provide individual training for AF personnel in the operation of Titan, Atlas and Thor missiles are to be located at Keesler AFB, Miss.; Chanute AFB, Ill.; and Sheppard AFB, Tex. Project is estimated to cost in excess of $11 million.



TELLING THE MISSILE WHERE TO GO

. . . and how to get there!

The button is pushed. The missile rises from the launching pad – slowly – then roars into space.

But the problem has just begun! Now the "brain" inside the missile takes over. This is the crucial part of missile warfare.

The target must be found – or met head-on – or overtaken. The missile must be *steered*. It must change course, double back if necessary. It must "think" its way to the enemy.

What ITT is doing about it

Since 1949, top scientists in ITT laboratories have been deeply engaged in missile guidance and control. They are deeply engaged now – playing a big role in national defense–working with the Navy, the Air Force, the Army, universities and associated laboratories, and other manufacturers.

They developed the complete airborne guidance for TALOS, the Navy's deadly "flying fish" launched from guided-missile cruisers. They developed the complete guidance for the Army's LACROSSE, including ground, air, tracking, and computing equipment. They helped with RASCAL, an Air Force air-to-surface missile. They developed the launching and firing controls and test equipment for the Air Force's BOMARC missile. They are designing and building communication networks for the ATLAS intercontinental ballistic missile.

Experience—where it counts

ITT is especially qualified for missile guidance development–because of long experience and special skills in air navigation and radar.

Other skills count heavily too – in infrared detection and homing, direction finders, inertial systems, computers, semi-conductors. ITT is also rich in these skills, and has the research laboratories and expanding manufacturing plants to carry the work forward.

Depend upon it – when the missile is launched, it will know where to go . . . and how to get there.

. . . the largest American-owned world-wide electronic and telecommunication enterprise, with 80 research and manufacturing units, 14 operating companies and 128,000 employees.

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Ramjet Fuels

(CONTINUED FROM PAGE 37)

that those fuels listed in the table on page 37 show promise. Only a small number of stable compounds listed there show significantly higher S_f than conventional hydrocarbons. Disallow molecular hydrogen for its poor physical properties and beryllium for its scarcity, and only the borohydrides and their derivatives remain as competitors to the hydrocarbons. Diborane suffers from a low boiling point (−134.5 F) and low density (0.447 gm/cc). Pentaborane, however, which has 50 per cent higher heat content than an equal weight of gasoline, has somewhat better physical properties. Numerous derivatives of the boron hydrides with acceptable physical properties are becoming available.

Here we may point out that the physical state of the products of combustion can influence appreciably the expected performance of a ramjet engine. Variation in the air-fuel ratio which changes the temperature of the exhaust gases can affect the physical state of combustion products. Thus, the performance of a fuel cannot be evaluated at only one air-fuel ratio, or, even more simply, from heat of combustion alone. For instance, superiority of boron and its derivatives over hydrocarbons shows clearly on the very fuel-lean side of stoichiometric ratio but becomes much less pronounced at exhaust gas temperatures where boron oxide exists as a vapor. The advantage of pentaborane over gasoline drops from 55 to 16 per cent when this phase change occurs. Engine designers must keep this effect in mind.

A theoretical thermochemical analysis of ramjet performance, which assumes instantaneous and complete conversion of chemical to mechanical energy, leads unambiguously to the selection of the fuels shown in the table on page 37. An analysis based on kinetics of a fuel—its burning rate, ignition properties, evaporation rate, etc.—could lead to a different rating of fuels, especially for engines expected to operate under unusual conditions.

Some kinetic problems of importance are the following:

1. Stable intermediate products and energy states of the combustion reaction can reduce the energy available as thrust by taking an excessively long time to react completely in the combustion cycle. This time might be so long that partially oxidized combustion products will leave the engine before they contribute all the available energy.

2. The rate at which the fuel can be mixed with the oxidizer affects the combustion cycle in a similar way. Physical properties of the fuel and diffusion rates for liquids of low volatility, of solids suspended in a liquid, or of solids enter here.

3. Radiant heat transfer to engine walls can cause significant losses of energy if the reaction products include strongly radiating solid or liquid particles or carbon or boron-rich skeletal structures.

4. Flame stabilizers, needed for many fuels to start the combustion process, fix the flame within the engine and promote the rate of flame spreading but cause drag losses and reduce overall engine performance.

One important function of the ramjet engineer is to keep all these energy losses to a minimum for any chosen fuel by appropriate motor design. Hydrocarbon fuels, with the exception of acetylene and its derivatives, have rather poor kinetic performance. They require, for instance, elaborate ignition sources and stabilizers to maintain combustion at an acceptable rate under adverse flight conditions. Fortunately, at higher flight speeds the pressures in the ramjet are usually high enough to allow hydrocarbon fuels to be used without severe losses from their poor kinetics.

The question of additives can be raised here, for they have been suggested as a means of improving the rate of hydrocarbon combustion. A fuel additive may be defined as a substance, present in an amount of, say, less than 1 per cent by weight, that influences combustion to an appreciable degree. Extensive investigations of many potential additives to hydrocarbons indicate that they affect combustion efficiency and stability by a negligible amount. In general, and as typified by diborane-propane mixtures, the influences of additives is less than would be expected from a concentration affect alone. It can be concluded that the rate-determining reactions in flames are not very sensitive to the addition of small quantities of a second substance.

Storage Affects Possible Use

The need to store a fuel and have it ready for use over a wide temperature range will affect its possible use. Fuels that react rapidly with air or water can cause major storage problems. Diborane and pentaborane vapors, for example, may ignite spontaneously on coming in contact with air, and they rapidly hydrolyze, evolving hydrogen and precipitating boric acid. Finely divided metals also oxidize rapidly in air. Straight-chain hydrocarbons with more than nine carbon atoms solidify above −30 F, and, in highly branched or unsaturated forms, solidify at even higher temperatures. Finely divided metals are difficult to keep suspended in liquids unless they are stabilized by a highly viscous additive or by shaping them into platelets, etc.

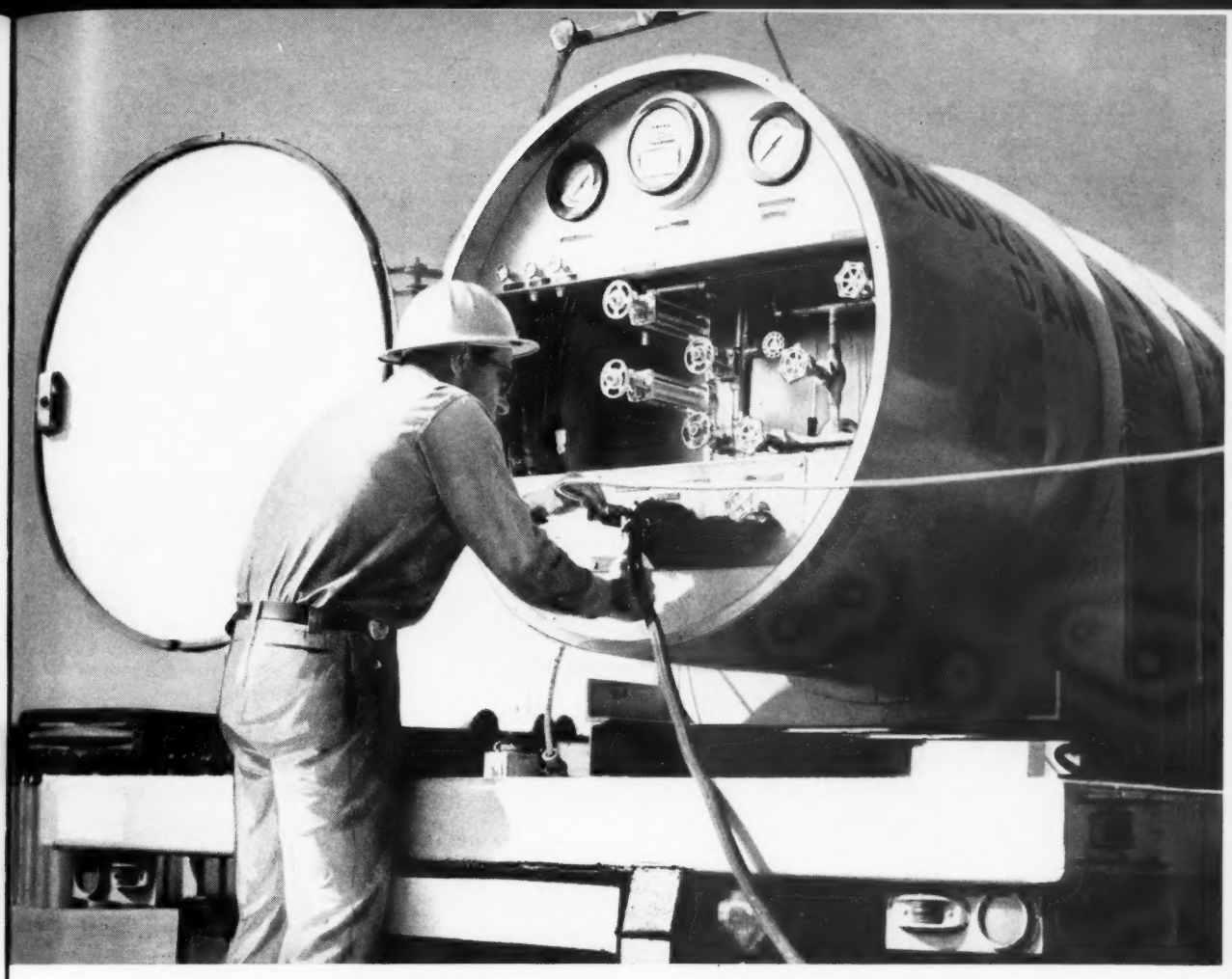
When we come to the thermochemically promising fuels that are relatively low in cost, readily available, have acceptable kinetics, do not produce undesirable exhaust products, and can be stored and handled safely without major practical handicaps, we find that none can compete on all points with the common petroleum derivatives. Only exceptional demands of thrust, the need for highest fuel economy, or very adverse conditions of engine pressure and temperature environment can justify the use of high-energy or highly reactive fuels.

Yet these demands do occur for the very advanced new powerplants, and for these reasons the virtues of nonhydrocarbon fuels for particular applications present sufficient justification for intensive investigation.

AVAILABILITY AND COST OF POTENTIAL RAMJET FUELS

Fuel	Molecular weight	Heat of combustion (Btu/lb)	Cost ($/lb)	Annual production (United States, 1957)	Available energy (Btu/year)
Hydrogen	2	61,000	2.36	0.1×10^6 tons	1.2×10^{13}
Beryllium	9.0	26,900	270	1160 tons	1.7×10^{10}
Boron	10.7	23,300	9.0	0.315×10^6 tons (B_2O_3)	0.44×10^{13}
Coal	—	14,000	0.005	390×10^6 tons	960×10^{13}
Gasoline	—	18,000	0.008	1500×10^6 barrels	570×10^{13}
Kerosene	—	18,000	0.005	125×10^6 barrels	46×10^{13}
Acetylene	26.0	21,400	0.35	0.3×10^6 tons	1.2×10^{13}
Sodium	23.0	4,000	0.19	0.13×10^6 tons	0.1×10^{13}
Magnesium	24.0	10,800	0.36	0.075×10^6 tons	0.18×10^{13}
Aluminum	27.0	13,300	0.25	1.6×10^6 tons	4.0×10^{13}
Iron	55.8	3,000	0.10	100×10^6 tons	60×10^{13}

Based on a paper presented at the ARS 12th Annual Meeting in New York City, December 2-5, 1957.



TAMED: *the elemental fury of fluorine!*

Still thinking of elemental fluorine as "too hard to handle"? Not any more! As a result of General Chemical research, this "optimum" oxidizer can now be stored, transported and handled directly *as a liquid* in tank-truck tonnages. If you are interested in working with fluorine as an oxidizer for rocket fuels, or for any other application, this development could be of major importance to you.

Benefits of liquid fluorine. Now that fluorine is available in liquid form and in bulk quantities, you can handle and store it more easily, more safely and more economically than ever before. An important *plus* value—the shipping containers can also be used as storage tanks.

Halogen fluorides also available. The halogen fluorides, too, are commercially available from General Chemical. Chlorine trifluoride is available in ton cylinders and cylinders of 150 lbs. net. Bromine trifluoride, bromine pentafluoride and iodine pentafluoride are offered in various-sized cylinders to suit demand.

Write for free technical bulletins. A comprehensive new technical bulletin, "Fluorine," will be sent you on request. Also Technical Bulletin TA-8532-2, covering Chlorine Trifluoride and other Halogen Fluorides. Write for your free copies today.

Allied Chemical

First in Fluorine Chemistry

GENERAL CHEMICAL DIVISION

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People in the news

Dorman Geckler

Gore Rogers

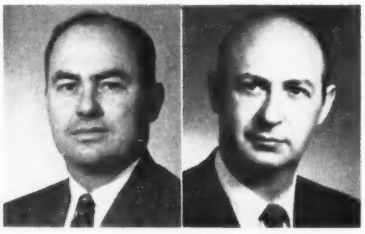
Warfel Dempsey

APPOINTMENTS

Five newly elected vice-presidents at Aerojet-General and their respective fields of operations are: **Bernhardt L. Dorman,** test engineering; **Richard D. Geckler,** Sacramento solid rocket plant; **William L. Gore,** customer relations; **William L. Rogers,** Azusa operations; and **John S. Warfel,** avionics.

James R. Dempsey, general manager of Convair-Astronautics, has been elected a vice-president of Convair Div. of General Dynamics.

W. Kenneth Davis, former director of the AEC Reactor Development Div., has been elected a vice-president of Bechtel Corp. He will head up the company's activities in space, nuclear and scientific development.



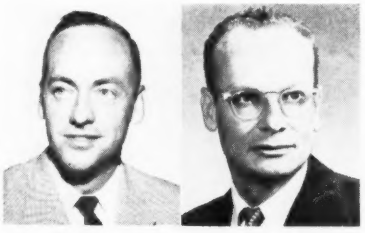
Davis Levine

Edward E. Harriman, senior systems engineer, Navy BuOrd Air Weapons Systems has been named scientific adviser to Defense Secretary William M. Holaday. Harriman will also serve as executive secretary of the Scientific Advisory Committee for ballistic missile programs.

Brig. Gen. Daniel Edwin Hooks has been appointed commander of the Air Force Missile Development Center, Holloman AFB, N.M.

C. P. Pesek, vice-president, engineering and staff manufacturing, Minnesota Mining & Mfg. will direct the newly formed Missile Industry Liaison group, headed by **W. R. Ludka.**

The newly formed ITT Labs, combining the research facilities of Farnsworth Electronics Co., Kellogg Switchboard and Supply Co., and Federal Telecommunication Labs has named five new vice-presidents of the respective fields: **Arnold M. Levine,** missile systems; **Louis A. de Rosa,** electronic countermeasures; **Sven H. Dodington,** avionics; **Armig G. Kandoian,** communication systems; and **Charles D. W. Thornton,** physical sciences, components and instrumentation. **Brig. Gen. Peter C. Sandretto** (USAFR) and **Andre G. Clavier** will continue as vice-presidents and technical directors, government and commercial projects, respectively, positions they previously held at FTL. **Dudley M. Day** will serve as administrative vice-president, secretary and treasurer, while **Henri Busignies,** as president, will direct the overall activities of the laboratories. **Donald M. Culler** will



Hedberg Harriman

head ITT's newly established Astrionics Laboratory, Fort Wayne, Ind.

Maurice C. Foster and **James H. Hedberg** have joined Aerolab Development Co. as project engineer and special project engineer, respectively. Hedberg was formerly with Firestone's Guided Missile Div.

G. M. Giannini & Co. has appointed **Thomas J. Harriman** director of engineering. He formerly was director, engineering, at Bell Aircraft's Special Weapons Div.

Capt. Frank A. Escobar (USN-Ret.) has joined Fairchild Guided Missiles Div., as assistant to general manager Grayson Merrill.

The Air Force has appointed **Brig. Gen. Homer A. Boushey,** deputy director of R&D, to the new post of director of Advanced Technology.

Douglas W. Hege, program manager, Atlas engine effort, Rocketdyne, has been named manager of the Advance Design Section, during the absence of George P. Sutton, ARS national president, who has been appointed Jerome Clarke Hunsaker Professor of Aeronautical Engineering at MIT, as noted.

Richard J. Coar, former assistant chief engineer at Pratt & Whitney's Florida R&D Center, has been promoted to chief engineer, advanced projects.

Edward R. Nauman, former propellant manager, Thiokol Chemical, has been appointed general manager, Longhorn Div.

Coar Nauman

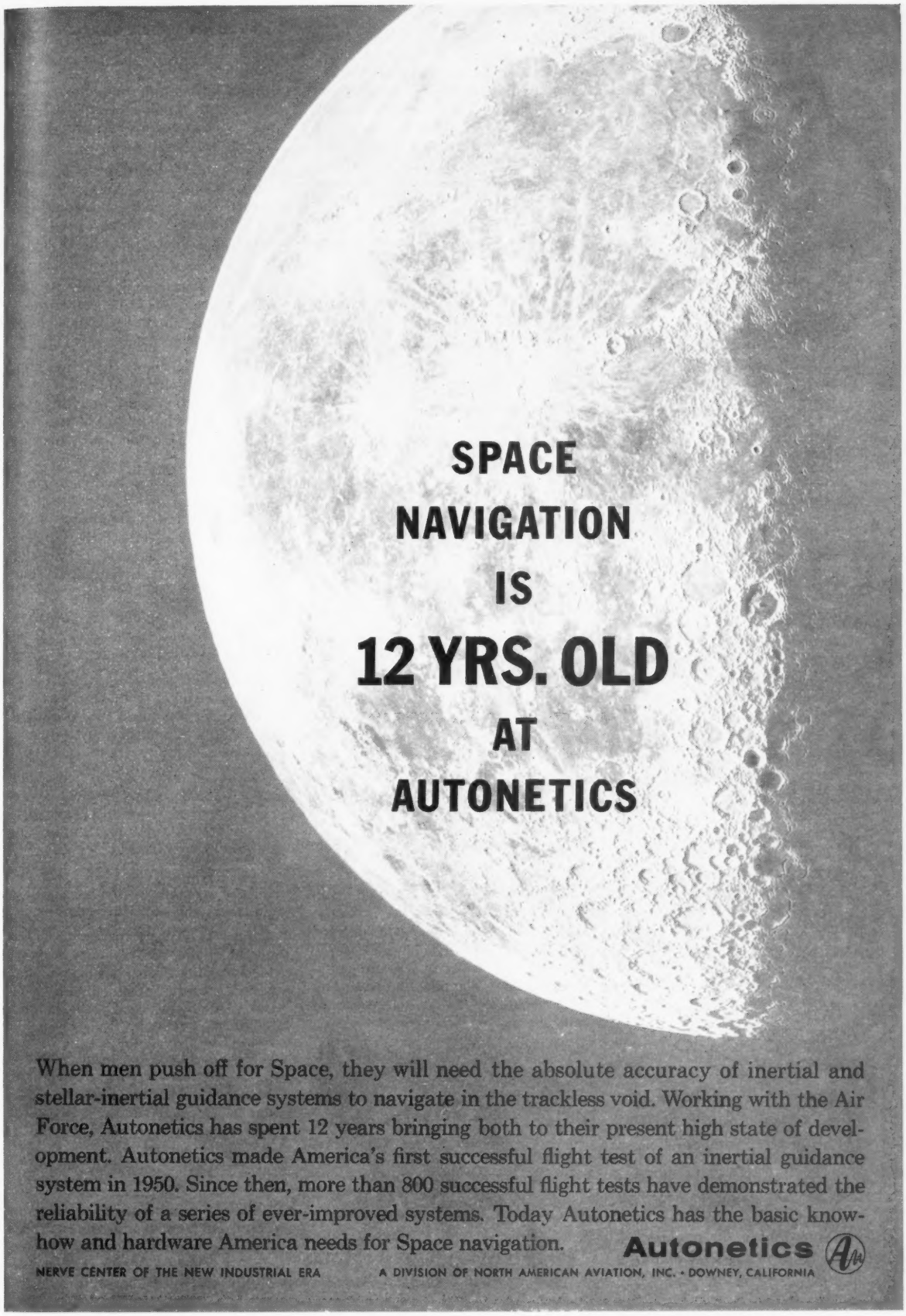
Wyandotte Chemical has appointed **William A. Cuddy** to head the liquid propellant combustion section, Contract Research Dept., Research and Engineering Div.

Leston Faneuf, re-elected president of Bell Aircraft, also has been elected board chairman, while **Harvey Gaylord** has been elected to the newly created position of senior vice-president.

Milton Glossa has been named senior engineer, Advanced Ground Based Systems Development, Martin-Denver Div.

Howard M. McCoy has been named assistant to the executive vice-president, Marquardt Aircraft Co.

W. W. Fox has been appointed as-



When men push off for Space, they will need the absolute accuracy of inertial and stellar-inertial guidance systems to navigate in the trackless void. Working with the Air Force, Autonetics has spent 12 years bringing both to their present high state of development. Autonetics made America's first successful flight test of an inertial guidance system in 1950. Since then, more than 800 successful flight tests have demonstrated the reliability of a series of ever-improved systems. Today Autonetics has the basic know-how and hardware America needs for Space navigation.

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Positions available for qualified personnel. Write Mr. Walter Hatcher.

sistant chief engineer of Convair.

Philip de Beixedon, former chief project engineer and staff adviser, Holmes & Narver, has been named planning director at Pacific Automation Products. **J. C. Fletcher,** former director, Ramo-Wooldridge Electronics Lab, has been appointed president of PA's new subsidiary, Space Electronics Corp. **Frank W. Lehan** and **Howard Skouby** become vice-president and treasurer, respectively.

Fletcher and Lehan

Milton A. Chaffee, formerly director, electronics and systems research, Fairchild Camera and Instrument Co. will head the new research department at Bendix Aviation's Radio Div., which is expanding its research program in space physics. **Harry D. Huskey,** associate professor, electrical engineering and mathematics, Univ. of Calif., will head the newly formed Advanced Programming Development Group at the Bendix Computer Div.

Everett J. Long, former assistant director, operations, Consolidated Electrodynamics Transducer Div., has been promoted to director of the division.

Consolidated Diesel Electric Corp. has appointed **John A. Grimes,** general manager of its Test Equipment Div.

Charles L. Davis and **W. T. Noll** have been named general manager and assistant general manager, respectively, Minneapolis-Honeywell's Aeronautical Div. Davis was formerly manager, sales, planning and research; Noll, manager, production, procurement and personnel.

Noll **Johnson**

Richard M. Johnson has been elected president, Koehler Aircraft Products Co.

Thompson Products has appointed **Frank A. Flower** manager of its new Washington office and **Arthur R. Christie** senior consultant.

Lynn Bly, former director, manufacturing, Air Logistics Corp., becomes assistant chief engineer, Horkey-Moore Associates.

Col. Paul H. Scordas has been appointed Chief, U.S. Army Ordnance District, Los Angeles, succeeding **Col. J. E. Johnston,** who has been reassigned as Chief, Detroit Ordnance District.

AEC has appointed **Harry H. Gorman,** manager of the commission's newly established Lockland, Ohio, Aircraft Reactors Operations Office.

Brig. Gen. Albert H. Schwichtenberg has been named to head the new Dept. of Aviation and Space Medicine, Lovelace Foundation for Medical Education and Research, Albuquerque, N.M.

Roland W. Larson has been named assistant Talos Div. Supervisor at the Applied Physics Laboratory, Johns Hopkins Univ., while **Billy D. Dobbins** becomes supervisor, Talos Guidance Development and Research Group.

Rear Adm. Selden B. Spangler (USN-Ret.) has been appointed director of research at Garrett Corp.

Charles W. Sinclair, former chief engineer, Automotive Div., Kelsey-Hayes Co., becomes vice-president, engineering, for all of the company's divisions.

Donald Z. Erle has become chief engineer, fluid control devices, Hydrodyne Corp. He formerly headed up the hydraulic design engineering group at Bendix Pacific.

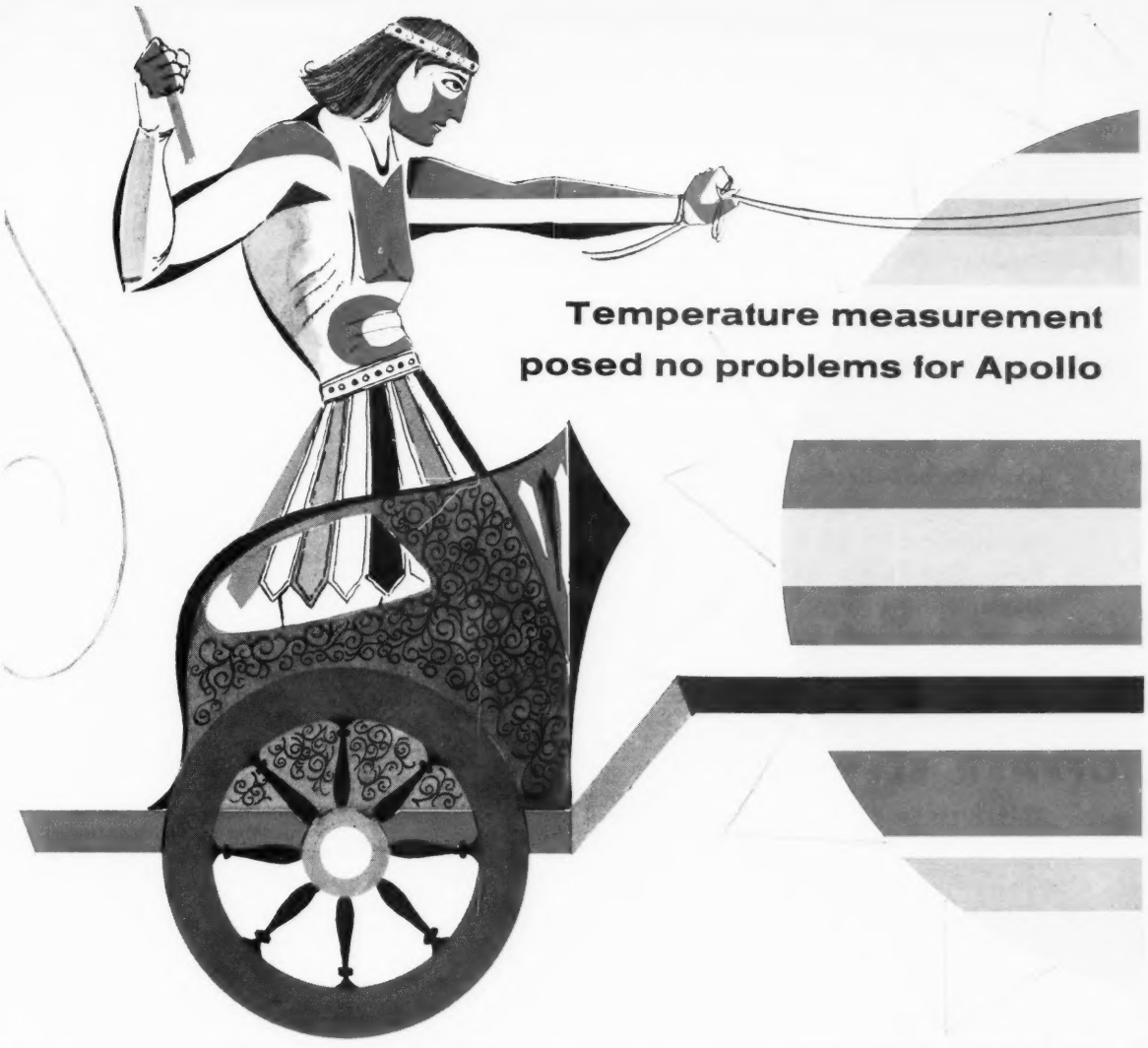
Jay J. Newman has been appointed manager, defense planning, RCA Semiconductor and Materials Div.

James L. Anast, former technical director of the Government's Airways Modernization Board, has been named assistant to the president for technical planning at Lear's Washington offices.

Leslie D. Myers has been promoted to chief manufacturing engineer, Lockheed's Missile Systems Div. **Emil J. Docekal** succeeds Myers as plant engineer, Georgia Div. and **J. V. Saylors** succeeds Docekal as general foreman, General Maintenance Dept.

Randal M. Robertson, former director, ONR Research Group, has joined the National Science Foundation as assistant director, mathematical, physical and engineering sciences.

(CONTINUED ON PAGE 78)



Temperature measurement posed no problems for Apollo

...and you'll have none with the MRC Universal Temperature Measuring System

When Apollo was ranging the heavens he had no temperature problems because he was God of the Sun. Today's missile engineers, being mortal men, have had to find the vital key to many temperature problems in the race to conquer space. Now... after years of development, Magnetic Research Corporation has solved these difficult problems with the Universal Temperature Measuring System. A system so reliable... so accurate... so versatile under all conditions, that it reduces the measurement of temperature to a routine procedure.

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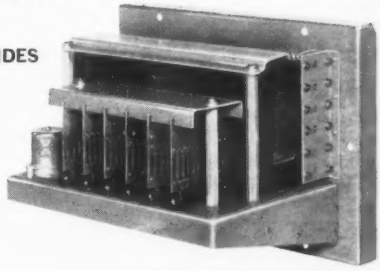

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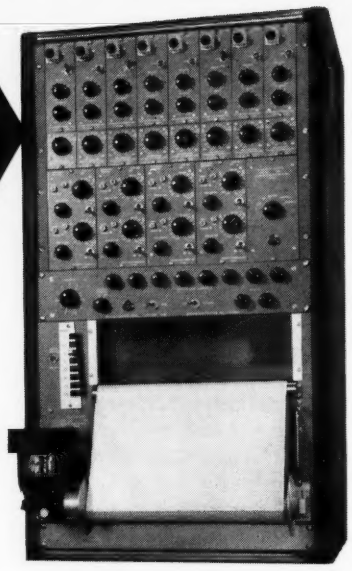

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I_{sp}: How High for Chemical Fuels?

(CONTINUED FROM PAGE 27)

hydrogen is used as a working fluid; and, at that, the maximum temperature is limited by the properties of heat-transfer materials in the reactor and engine system.

This does suggest the interesting possibility of obtaining very high specific impulse for space flight—about 1000 sec for small thrusts—by using a parabolic mirror and heating hydrogen to, say, 3000 K in a tungsten container.

Propellant Limitations

Chemical propellants, which are heated by their own reaction and not externally, are limited not by temperature, but by heat of reaction per unit weight. The second table, on page 35 gives heats of reaction to form the compounds shown. The first column gives the heat release for the state stable at ordinary temperatures. The second column, which is for compounds which are ordinarily solid, gives heat release to form a vaporized compound. If temperatures are so high that these materials are present as vapor, the value in the second column must be used.

With the usual fraction of 50 to 60 per cent of total heat content converted to kinetic energy, even the most energetic of propellants—beryllium and fluorine to form BeF_2—give a specific impulse of only 450 sec. Combustion temperature would be on the order of 5000 K (8000 F), even allowing for dissociation effects. This is beyond the capabilities of present nozzle cooling systems, especially since neither of the propellants could be used for cooling. The question may then be asked: Are there not some propellant combinations which will give greater heats of reaction on a weight basis? The answer is yes, but for the usual types of chemicals only to a very small degree. Hydrazine (N_2H_4) has a small negative heat of formation (0.38) kcal/gm) and so gives a greater heat release on burning than the equivalent amount of a mixture of hydrogen and nitrogen.

Certain free radicals can give much higher heat release. Ozone, which can be considered a free radical, increases the heat of reaction with hydrogen to form water from 3.21 to 3.84 kcal/gm. Other free radicals, such as NH or CH, would add much more heat to chemical reactions—on the order of 5 kcal/gm. And, of course, atomic hydrogen, adding 51 kcal/gm, is best of all.

The stabilization and storage of free radicals is, however, a knotty problem. Even ozone, considered one of the most stable of free radicals, has proved disappointingly unstable in the limited experimental work done with it. Radicals with higher energy contents may be expected to be correspondingly more unstable.

With severe limitations on the heat content that can be put into propellant gases, the obvious factor to improve is the fraction that can be converted to kinetic energy, or thrust. We have given the usual conversion fractions as 50 or 60 per cent. Increasing this to 100 per cent would give increases of 41 and 29 per cent in specific impulse in the two cases because of the square root relationship. Although increases would be appreciable, they involve a number of theoretical and practical problems.

Theoretical Difficulties

One theoretical difficulty common to all propellant gases is that 100 per

cent conversion would require an infinite pressure expansion ratio. Another is the fact that, at the low temperatures and densities for the latter part of the expansion, part of the heat content of the gases may be "frozen-in" and thus would not contribute to the conversion. Practical difficulties are present in the large size and weight of nozzle required for high expansion ratios.

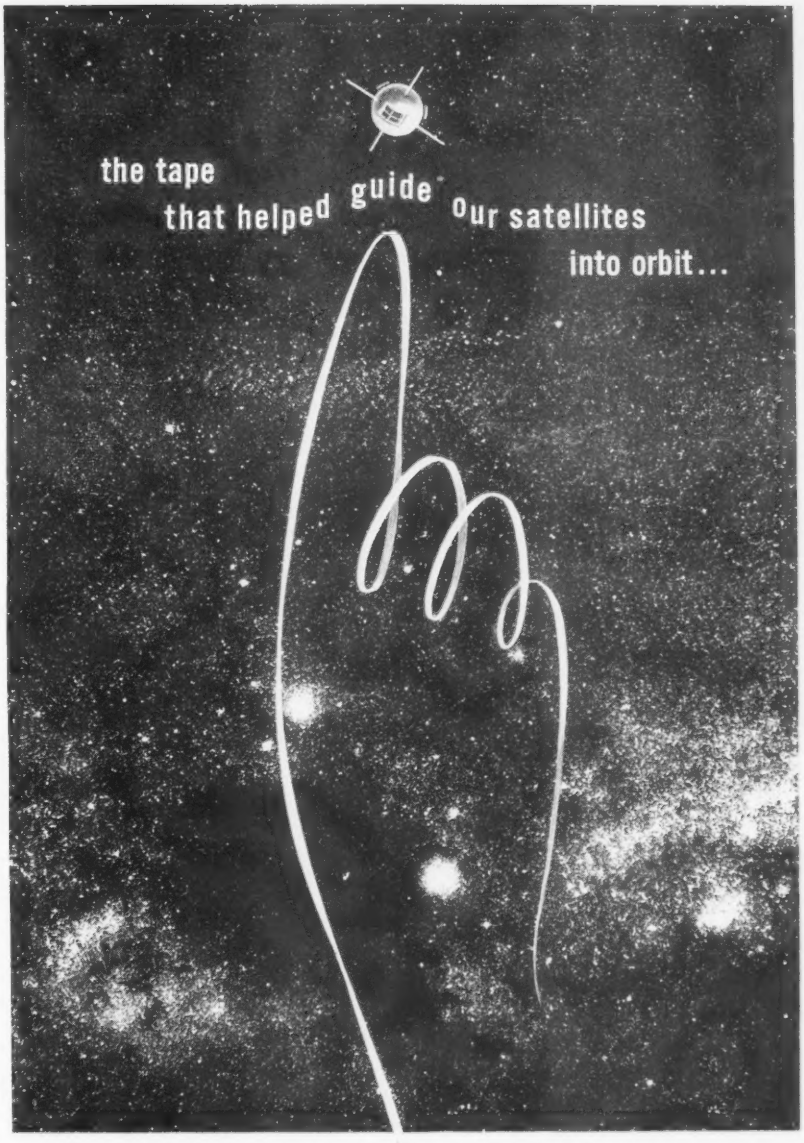
There are, however, large differences in the fractional conversions of heat content among the various propellant gases. This efficiency of heat conversion is determined by the isentropic expansion exponent of the gases. The exponent itself depends upon the heat capacity of the gas, upon the degree of dissociation present, and, in extreme cases, on the time in which the expansion occurs. This exponent determines the temperature drop for expansion over a given pressure ratio. The larger the exponent, the greater the temperature drop, and hence heat converted to kinetic energy. In common terms used in rocketry, the higher the specific heat ratio (γ), the larger is the fraction of heat content converted to thrust.

Consequently, conversion is greatest for the simplest, most stable gas molecules. This is the reason that hydrogen fluoride, with the same heat of formation as steam, gives a specific impulse some 8 per cent higher. Under the conditions given, the energy conversion for the F_2-H_2 system is 59.3 per cent, but for LOX-H_2, it is only 51.5 per cent.

The third table lists a number of propellants in order of increasing performance. The conditions taken are a combustion pressure of 200 psi, pressure expansion ratio of 75, and a well-designed regeneratively-cooled engine, so that combustion temperatures are not limiting.

The first two are typical of present propellants. The first is in use, the second represents a storable combination. The third, LOX-N_2H_4, represents a system which could be easily developed in a short time and at relatively low cost. The last three represent major developments involving either liquid hydrogen, liquid fluorine or both. These three also represent the best that can be developed in a reasonable time, with the usual type of straight chemical propellants, to give significant increases in performance.

Specific impulses for these propellants illustrate the fact that it can be somewhat misleading to use formulas derived from the properties of perfect gases to choose desirable parameters for propellants. It is frequently stated



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that, to obtain maximum specific impulse, temperature should be as high as possible and molecular weight and specific heat ratio as low as possible. *The actual factors to be maximized are initial heat content per unit weight and the fractional conversion of this heat,* which calls for a maximum isentropic expansion exponent.

Performance Would Be Fantastic

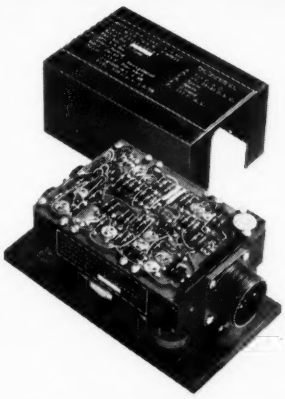
It is true that if temperature, molecular weight and specific heat ratio could be chosen independently, really fantastic performances could be obtained. Unfortunately, they are all rather intimately related, so that changing one of these factors usually changes the others in the direction we do not want.

Somewhat higher specific impulses could probably be obtained by unconventional approaches. For example, a suspension of lithium or beryllium hydride in hydrazine, burned with lox or fluorine should increase performance appreciably. Hybrid systems, using a nuclear reactor at reasonably low temperatures (1750 K) to gasify metals with high heats of vaporization, as reported recently by Green and Carter, would give performance values of 350–450 sec with the expansion ratios given in the third table.

Another approach, aimed not at improvement of specific impulse but at decreasing the weight of the engine, tanks, etc., would decrease the "parasitic payload" and increase the net impulse of propellants. Perhaps more important, it would decrease costs to a marked degree. Propellants now cost a few cents to a few dollars a pound, while hardware, depending on the number of units involved, usually runs $100 a pound. A significant reduction in total cost would thus come from decreasing hardware weight. In addition, for a given performance level, any reduction in dead weight could be put into payload. One example, more or less close to present practice, will illustrate how important it can be to cut hardware weight. With a hardware-to-propellant ratio of 1:10 and a payload amounting to 20 per cent of total weight per stage, decreasing the hardware-to-propellant ratio to 1:12 increases the payload to 21.8 per cent of total weight, or nearly 10 per cent. For a two-stage vehicle the increase in payload is 21 per cent, and for three stages 33 per cent.

Moral: Ingenuity in choice of materials and in design to minimize hardware weight gives higher net impulses just as definitely as does improvement in the propellants themselves.

NEW LIGHT-WEIGHT STATIC INVERTER PROVIDES SINE WAVE POWER



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What do You Know About Space?

(CONTINUED FROM PAGE 25)

(1) an error in the planetocentric escape hyperbola ($v \pm 10$ fps); (2) an error in the scalar value of the heliocentric departure velocity ($\Delta v \sim \pm 10$ fps); (3) an error in the angular direction of the heliocentric departure vector ($\Delta\beta \sim \pm 0.5°$); (4) an error in cut-off altitude of the vehicle upon entering the escape hyperbola; (3) an error in transfer time due to any of the errors, a, b, c

94. For drag-free vertical flight of a constant-thrust single-stage rocket, the burnout velocity depends on each of the following parameters (directly or indirectly) except one. Identify that one:

(1) Ratio of gross weight to frontal area; (2) Thrust-to-gross-weight ratio; (3) Specific impulse; (4) Ratio of gross mass to propellant mass; (5) Ratio o propellant mass to empty mass

95. If a 5000-mile range ICBM rocket system is to be used to project a satellite into a low altitude circular orbit (200-mile height), the minimum necessary increment in burnout velocity is approximately:

(1) 10%; (2) 20%; (3) 30%; (4) 40%; (5) 50%. Choose the nearest figure

96. For the vertical flight of a multi-stage high-altitude research rocket, the summit altitude can be maximized by appropriate choice of the firing delay time (coasting period) between each stage and the next one. The optimum coasting period is:

(1) the exhaust velocity divided by the standard gravitational acceleration; (2) $1/e$ of the firing time of the preceding stage; (3) the burnout velocity of the previous stage divided by the gravitational acceleration; (4) the firing time of the previous stage; (5) zero time

97. Consider the drag-free straight-line flight of a multi-stage rocket in gravity-free space, starting from rest. The individual stages are similar to each other; each payload fraction is 0.2; the specific impulse values are the same; each stage by itself can produce a burnout velocity equal to the effective exhaust velocity. The final burnout velocity of the N-stage rocket is directly proportional to N. The required gross mass of the rocket per unit mass of the final payload is roughly proportional to:

(1) N; (2) N^2; (3) e^N; (4) 5^N; (5) $\log N$

98. Consider a space ship consisting of a payload M_L, a nuclear power plant which operates for a time t_0 delivering power W kilowatts and weighing $M_w = \alpha W$ kilograms, and a propellant of mass M_p which is expelled with exhaust velocity C at a mass flow rate, such that $M_p C^2/2 = W$. The highest velocity increment which this space ship can attain in free space is approximately:

(1) the velocity of light; (2) the velocity of sound in the propellant medium; (3) the exhaust velocity C; (4) $\sqrt{2t_0/\alpha}$; (5) $t_0/\alpha C$

99. To impart the maximum velocity increment to the above space ship, the exhaust velocity C should be:

(1) approximately equal to $\sqrt{2t_0/\alpha}$; (2) as high as possible; (3) the velocity of light; (4) approximately $t_0/\alpha C$; (5) the velocity of sound in the propellant medium

100. Suppose the specific weight of the power-plant of the above space ship is 10 km/kw, and a velocity increment of 20 km/sec in free space is to be attained. The average acceleration of the space ship under best possible conditions will then be approximately:

(1) 10^{-3} g; (2) 1 g; (3) 10 g; (4) 100 g; (5) 1000 g

101. Suppose that thrust is to be obtained by accelerating cesium ions through a potential of 1000 volts under space charge limited conditions. The net thrust per unit area will be proportional to:

(1) the ionization potential of cesium; (2) the square of the electric field strength at the source of ions; (3) the square of the electric field strength at the accelerator electrode; (4) the distance of separation of ion source and accelerator electrode; (5) the efficiency of ionization of the cesium

102. In order to attain rocket velocities equal to 25% or more of the velocity of light, we need above all else to have:

(1) more intense photon sources; (2) light weight fusion power sources; (3) fuels with higher specific energy than U-235; (4) magnetohydrodynamic propulsion; (5) much improved solar batteries

Nose Cone Re-entry

This Jupiter IRBM nose cone "landed in the pickle barrel" after a flight from Cape Canaveral in July over approximately the full range of the weapon. The cone was recovered by the Navy, and was safely aboard the USS Escape 1 1/2 hours after liftoff at the Cape.

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Balloonists Set Record

Balloonists M. Lee Lewis (left) and Comdr. Malcolm Ross stand beside gondola of 17-story balloon which rose to 82,000 ft altitude, and in which they rode for 34½ hours to beat by more than two hours the endurance record set last fall by Lt. Col David Simons. The flight, made from a pit at Crosby, Minn., was not designed to break altitude records, but to test the entire sealed gondola carrying system for a projected balloon flight in November to view the atmosphere of Mars, study effects of cosmic rays on some 10,000 insect passengers and test a television camera at high altitudes.

People in the News

(CONTINUED FROM PAGE 72)

NSF has also appointed **Earl G. Droessler,** formerly with DOD Office of Science, as program director of the newly established program for Atmospheric Sciences.

Walter Welkowitz has been appointed director, engineering, Vibro-Ceramics Div., Gulton Industries.

David M. Gardner has been named to the new post of project leader, missile propulsion chemicals research, Pennsalt Chemicals Corp.

Charles E. Crede, former vice-president and director of research and engineering, Barry Controls Inc., has been appointed associate professor, Cal Tech. He was former vice-president and director, research and engineering, Barry Controls, Inc., where he will continue as a board member and consultant. **Russell Lowe** becomes chief engineer; **Richard Cavanaugh** chief of technical staff; and **Bruce Backe** engineering business manager.

HONORS

Vivian O'Brien, engaged in aerodynamics research at the Johns Hopkins Applied Physics Lab., has been awarded the Amelia Earhart Medal for outstanding efforts in this area.

Mervin J. Kelly, president, Bell Telephone Labs has been awarded the 1959 John Fritz Medal for "his achievements in electronics, leadership of a great industrial research laboratory and contributions to the defense of the country."

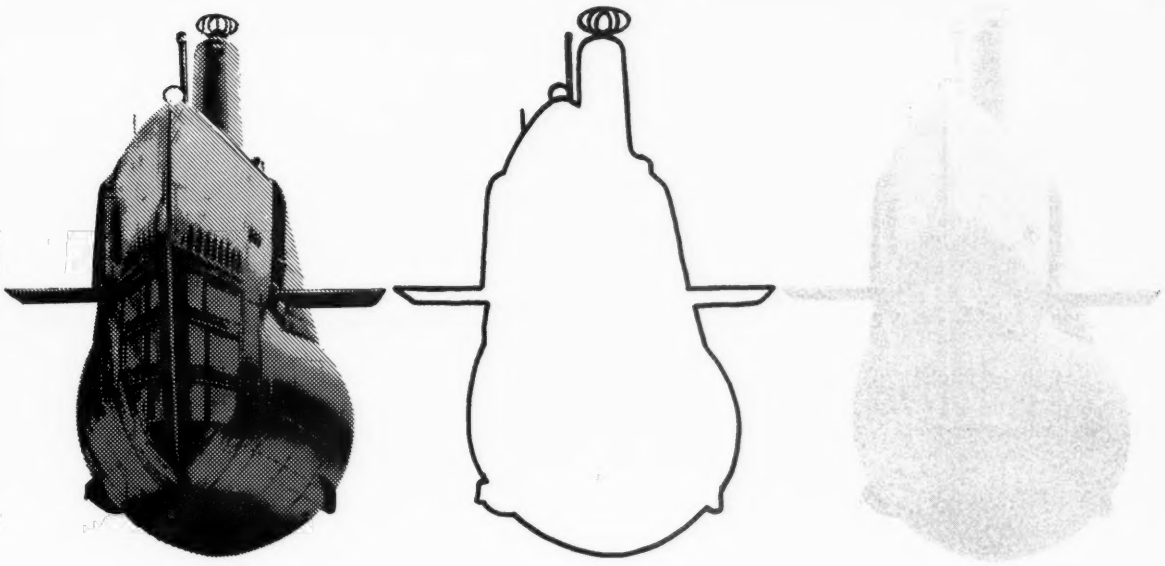
North American Aviation test pilot **Scott Crossfield** has won the IAS Octave Chanute award for notable contributions by a pilot to the aeronautical sciences. Crossfield, slated to test the X-15 for NAA, was given the award for "significant contributions to the knowledge of human factors involved in flight at extremely high speeds and altitudes."

DEATHS

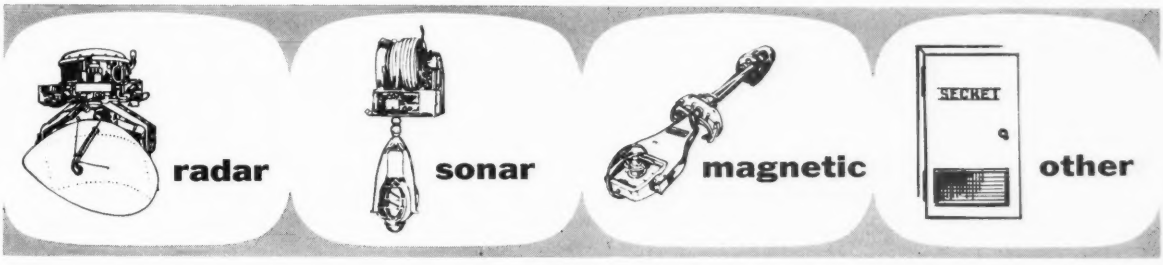
Everett B. Schaefer, chief engineer of Canadair Limited's Aircraft Div., died in Montreal July 9 at the age of 51. He was an instructor at the Daniel Guggenheim School of Aeronautics for eight years after he graduated from New York Univ. with master's degrees in mechanical and aeronautical engineering in 1930, and later held important positions with Cunliffe-Owen Aircraft Co. in England, Glenn L. Martin Co., and Boeing before joining Canadair in 1949.

A member of ARS, associate fellow of IAS, and fellow of the Canadian Aeronautical Institute, he received a citation from NYU's College of Engineering, three years ago for, "achievements which have brought distinction to his Alma Mater."

in antisubmarine warfare, it has to be . . .



YES or NO . . . not MAYBE!



It takes a lot of faith in your radar, sonar and/or magnetic detection equipment to leave an area with a "clean" stamp . . . even more faith than it takes to believe the blip that shouts "sub below." Such confidence-building equipments are not developed overnight . . . indeed, the technology spawning this gear at Texas Instruments dates back nearly thirty years to similar techniques in pinpointing subsurface mineral wealth. Since its entry into this complex field, TI has supplied literally thousands of detectors to the free world's navies . . . *operational* means of locating, tracking, and triggering counter-attacks against the subs that swim the sea.

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Optimum Paths

(CONTINUED FROM PAGE 21)

with a large impulse, like the sounding rocket, then bends over slowly with finite sustain thrust, smaller impulses at the beginning of each step followed by sustain periods, and, lastly, coasts after last-step burnout until the path comes tangent to the vacuum ellipse with the right velocity.

Oberth calls this his "synergic path" and estimates about 5–10 per cent increase in fuel to overcome drag. Precise determination of the path involves solving a problem in the calculus of variations. At present the curve is determined, for reasons of practicality, by thrust and acceleration limits.

The shape of the path near the moon is, of course, perturbed by the moon's gravitational field. To impact or come close to the moon, we must aim ahead of it and let it "run into" our vehicle. The vehicle's apogee velocity, if unperturbed by the moon, is 0.14 mps, whereas the moon's orbital velocity around the earth is 0.64 mps. Thus the minimum speed one could expect relative to the moon while still far away from it is about 0.50 mps.

In the moon's reference frame, neglecting the earth's influence, the vehicle will describe a hyperbola in falling toward the moon. How close the vehicle comes to the moon for this minimum initial velocity depends, in a most sensitive manner, on the velocity of launching and somewhat less sensitively on the angle of launching at the earth.

L. G. Walters gives ±15 fps (out of 36,400 fps) and ±0.8 deg as the tolerances to achieve moon impact. He also shows that a slight increase in initial velocity (300 fps) reverses the accuracy requirements for impact, making them ±100 fps and ±0.2 deg.

George Gamow and Krafft Ehricke have given vehicle paths for passing under the sun's influence very near the moon's surface. They show that to "ricochet" back toward the earth will require fantastically precise navigation. It can be assumed that a moon rocket should have some provision for homing and thrust control if any degree of accuracy for impact point is desired.

Use of Fuel in Braking

There is also the question of whether to use fuel to brake a vehicle returning to earth. Rather than carry precious fuel for a braking maneuver, we should like to take advantage of atmospheric drag to decelerate us. It seems likely that this re-entry problem will be solved in time, so that a returning vehicle will be able deliberately to graze the atmosphere on its first pass, penetrating deep enough to decelerate itself into an elliptical orbit around the earth, and in successive passes, perhaps five or six, reduce the size of this orbit until some aerodynamic lift device enables it to land directly or parachute to the surface.

The dynamic problems of interplanetary motion are essentially those encountered in an earth-moon journey, except that the sun's gravitational attraction acts as the primary controlling force, with the planetary forces providing perturbations at both ends of the flight. The interplanetary trip can thus be divided into three almost discrete steps: (1) Departure from earth, either from the surface or from a satellite orbit, along a hyperbolic path relative to the earth where the earth's attraction is dominant, (2) travel along an ellipse about the sun's attraction is dominant, and (3) approach to the target planet along a hyperbolic path relative to the planet where planetary attraction is dominant. The planetary orbits will be approximated as circular and co-planar.

To effect an Earth-Mars transfer, the space vehicle must be accelerated to perihelion velocity of the Earth-Mars Hohmann ellipse along a path tangent to the earth's orbit, as indicated in top diagram (a) on page 21. Since the earth's orbital velocity around the sun is 18.5 mps, the vehicle needs only an additional 1.88 mps once it is free of the earth's attraction.

The vehicle must therefore be accelerated to 7.21 mps tangent to the earth's surface (square root of the sum of the squares of 6.95 mps escape velocity and the 1.88 mps velocity increment) or to 4.78 mps if takeoff is from a satellite whose orbital radius is $^5/_4$ of the earth's radius. A satellite velocity of 2.18 mps will increase this 4.78 to 6.96 mps, which is the velocity necessary to escape from satellite orbit and enter the transfer ellipse.

Departing tangentially from the earth's surface allows a reduction in the velocity requirements, since the rotation of the earth about its axis provides a small velocity increment. In practice, departure will be along a "synergic curve" with slightly higher velocity requirements.

Diagram (a) on page 20 shows the departure from earth for Mars in terms of a nonrotating geocentric coordinate system. The assumption is made that the vehicle reaches final velocity in a very short time. This cannot be accomplished in practice, but the effect on trajectory will be small. An excellent discussion of finite acceleration time in taking off from a

Deep water to deep space

This is the span of Advanced Weapons studies at Chance Vought. Activities range from astrodynamics to oceanography.

They include ASW — new methods of undersea detection and classification.

Studies toward space research vehicles and manned spacecraft involve multistaging, space communications, nuclear and ionic propulsion, celestial navigation. A significant result of Vought's new space capability: membership on Boeing's Dyna Soar space glider development team.

Typical of the senior posts created by Vought's studies toward deep water and deep space are:

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ASTRODYNAMICS SPECIALIST
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Vought Vocabulary

ac′cu·ra·cy: *guided all the way, this long-range missile pinpoints distant, hard-to-hit targets*

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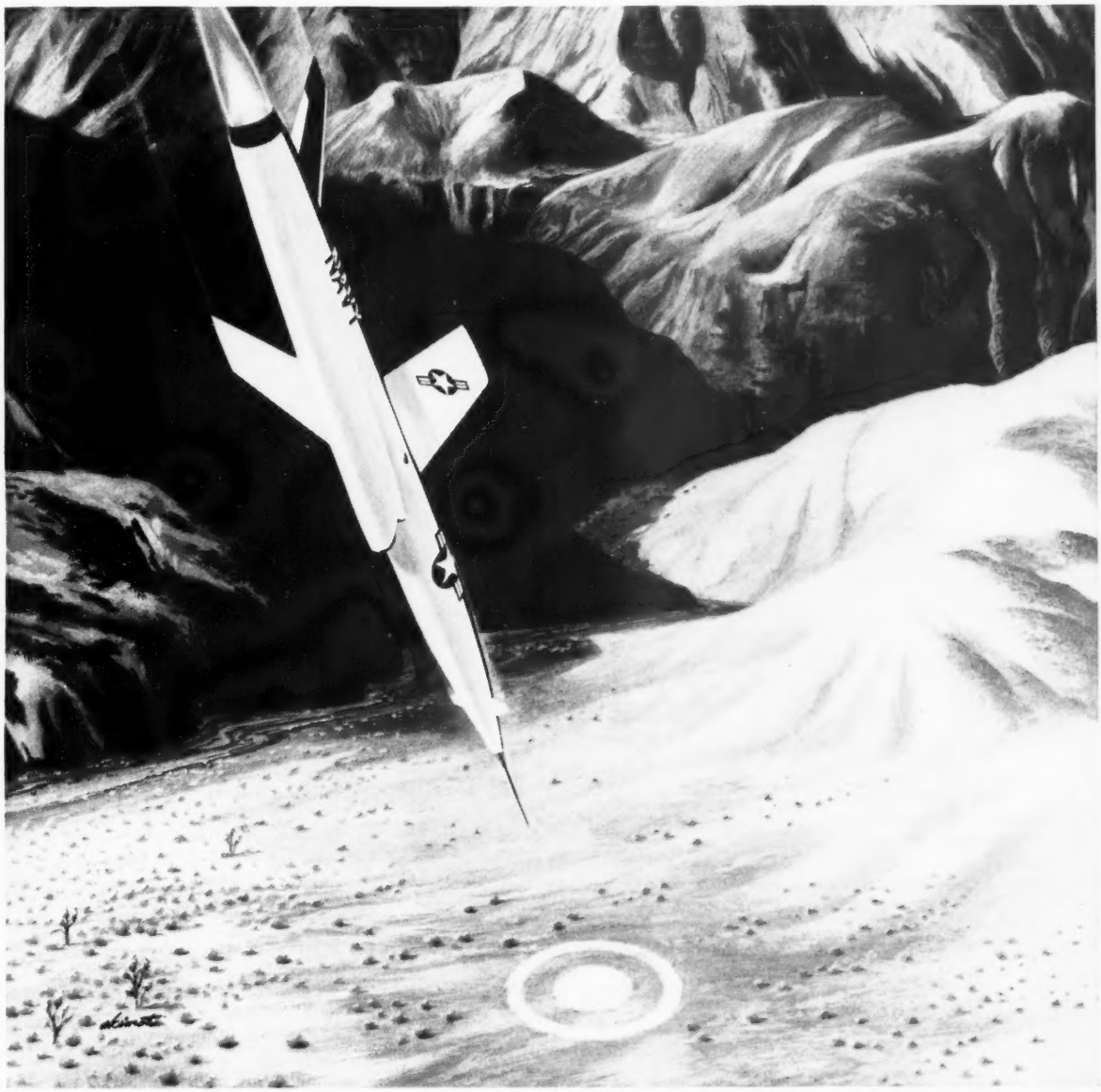

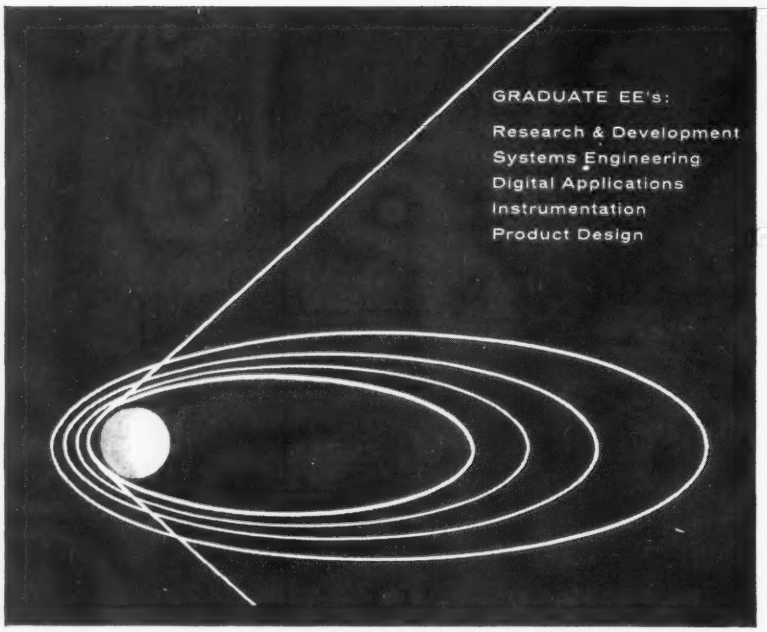

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The great technical challenges of guidance for space exploration lie in the unprecedented accuracies, reliabilities and long operative life-spans that must be engineered into the guidance systems.

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FOR WORK IN FRONTIER AREAS, look into the positions now open with the Section, on a number of stimulating, advanced projects.

Significant experience in 1 or more of these areas is desired:

Radar
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Forward your resume in strict confidence to
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MISSILE GUIDANCE SECTION

GENERAL ELECTRIC

Court Street, Syracuse, N. Y.

satellite orbit is given by Von Braun in his book, *The Mars Project* (University of Illinois Press, 1953).

As seen in figure (a), page 20, the vehicle leaves from "A" and moves away in a hyperbolic path, relative to the earth, that approaches asymptotically a line perpendicular to a radius vector from the sun. In sun coordinates this departure path appears to be only a small perturbation from the transfer ellipse, as in diagram (a) bottom of page 21.

After 259 days of travel along the transfer ellipse, the vehicle arrives in the vicinity of Mars. Here the attracting force of Mars perturbs the path so that, relative to Mars, the path appears hyperbolic. Since Mars is traveling faster than the vehicle, the latter appears to approach in a direction opposite to Mars' orbital motion, as shown in the illustration (b) on page 20. A retarding thrust must be applied here at "A" if the vehicle is to remain with the planet, that is, unless atmospheric braking is utilized.

The tables on page 20 give the velocity increments and other pertinent data referring to this transfer. The return trip is similar except for the departure and approach paths, which are shown in the illustrations (c and d), respectively, on page 20. The figures also apply to the Earth-Venus trip, whose constants are included in the tables. Calculations in the tables are based on data in *Astronomy* by John Charles Duncan (Fourth Edition; Harpers, New York, 1946).

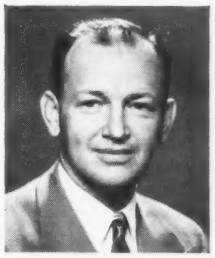
A Major Disadvantage

One major disadvantage of the Hohmann ellipse transfer is the requirement that time be spent waiting at Mars for the correct angular relationship between it and earth for the return trip. The waiting period for the Mars-Earth trip is approximately 455 days. The relative positions of the planets at arrival and departure are to scale in the top figures on page 21. M. Vertregt has worked out the requirements for nonoptimum transfer between two co-focal circular orbits such that, by following indirect routes, there are no rigid requirements on the initial positions of the planets or waiting periods, and transfer times are of the order of 100 days. The total energy requirement for this transfer runs one to three times the optimum value.

When the time for an actual Mars or Venus flight draws near, the eccentricities of the planetary orbits and their inclinations to the elliptic must be taken into account in the predicted path calculations. Since the astronomical parameters vary slowly with time, there is no point in making such calculations until they are needed.

HIGH TEMPERATURES
Key to Missile Performance

by John V. Long, Director of Research, Solar Aircraft Company



HIGH TEMPERATURE presents a formidable barrier to the advancement of missile technology. Present defense requirements call for temperatures ranging from −460F to way beyond the limits of known material capabilities. New and planned developments in atomic power and space flight will mean temperature levels far outside of man's current experience.

The temperatures encountered in missile development produce startling phenomena. They are part of today's problems—affecting the very concept of the new generation of high-Mach aircraft and missiles. Laboratory experiments have produced temperatures in the million degree range. Nuclear fission and fusion reactions produce temperatures even higher.

In the all out attack on the thermal barrier, scientists and material researchers are probing the four corners of the periodic table. The goal is to develop a practical solution to the thermal problem.

The highest melting material reported is a combination of the carbides of tantalum and hafnium. Its melting point is about 7200F. Difficulty of fabrication, however, precludes its use in present day applications. And 7200F is at the cold end of the high temperature spectrum. It is obvious, then, that a solution to the materials problem cannot be based on melting point alone. Man will never beat the thermal thicket by hitting it head on. Success will come only when he has devised new methods of ingeniously avoiding it.

There is an immediate need for a combination of materials and designs which will withstand temperatures of 2000F in jet engines —and at least 20,000F for re-entry vehicles.

In an all-out effort to satisfy some needs, materials researchers are re-evaluating available elements, combinations and processes. New techniques including vacuum metallurgy, zone refining, powder metallurgy, dispersion hardening and others are providing improved metals and alloys. Molybdenum, tantalum, rhenium and tungsten show promise because of their high melting points. But no known material has the refractory property or structural integrity to withstand the temperatures that will be encountered in tomorrow's "hotspeed" aircraft and missiles.

Extreme temperature resistance is not just a materials problem, but a problem of interaction between environment and the material of the vehicle. Designers must look at the system as a whole and design "around" high temperature problems. The use of heat sinks, ablation and transpiration cooling are partial solutions. Additional improvements will come with more research.

For the present we must learn to use available materials and, through design, provide the balance of the solution. We have by no means exhausted present material capabilities. Researchers must continue to refine and extend the high temperature performance of a variety of materials.

A comprehensive knowledge of both metals and non-metals and their physical characteristics in extreme environments is necessary for successful applications. The ability to fabricate useful structures is obviously a major criterion.

Best results will be obtained through a materials systems concept. This involves close coordination among raw materials suppliers, users, materials engineers, designers, test engineers, fabrication specialists and quality control engineers.

The team effort must be enthusiastic—and it must be dedicated to ultimate success through hard work.

Solar's capabilities are centered in a team of experts experienced in the many sciences related to missile and systems technology—from basic design to highly precise experimental, prototype and volume production. This backlog of experience is available for your important missile program. For information, write to Dept. F-57, Solar Aircraft Company, San Diego 12, California.

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PROVIDE THE ACCURATE POSITIONING ESSENTIAL FOR NUMERICAL CONTROL

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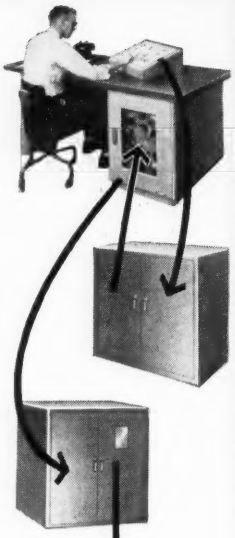
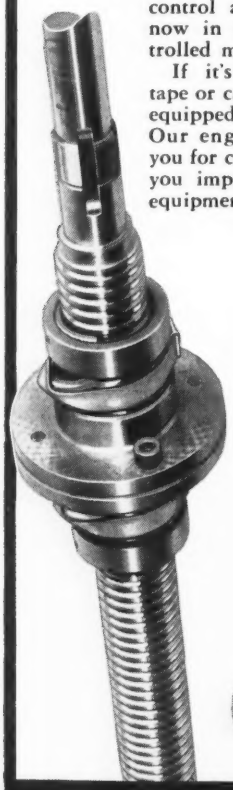
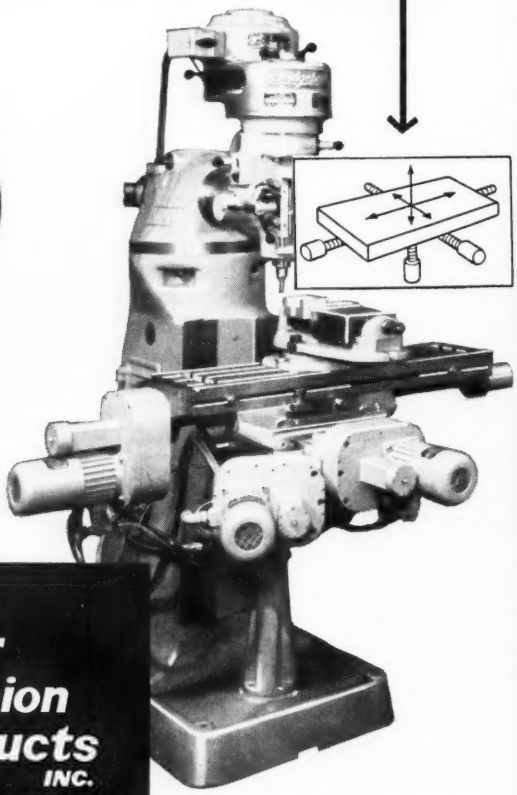
Beaver ball screws move table of this Bridgeport Mill in response to signals from the Electronic Control Systems, Inc. "Digimatic" control and are typical of those now in use on numerically controlled machine tools of all types.

If it's numerically controlled, tape or card, it is more than likely equipped with Beaver ball screws. Our engineers are available to you for consultation – can we help you improve the design of your equipment?







Beaver Precision Products INC.
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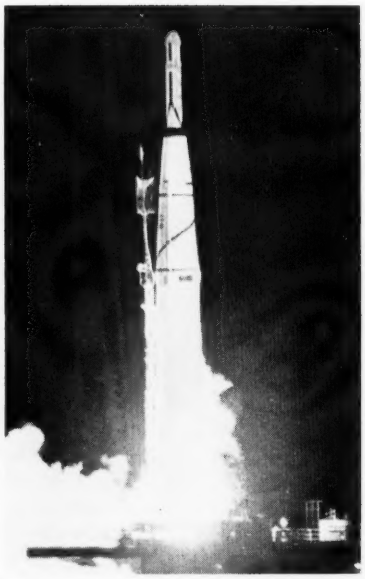
Marquardt Ramjet Engine Sets Endurance Record

Marquardt Aircraft Co.'s advanced XRJ59 ramjet engine was recently run continuously long enough to fly nonstop three times around the world at altitudes of more than 14 miles and at higher supersonic speeds than achieved heretofore by air-breathing engines. The mark was made in a test conducted at the Naval Ordnance Aerophysics Lab, Daingerfield, Tex.

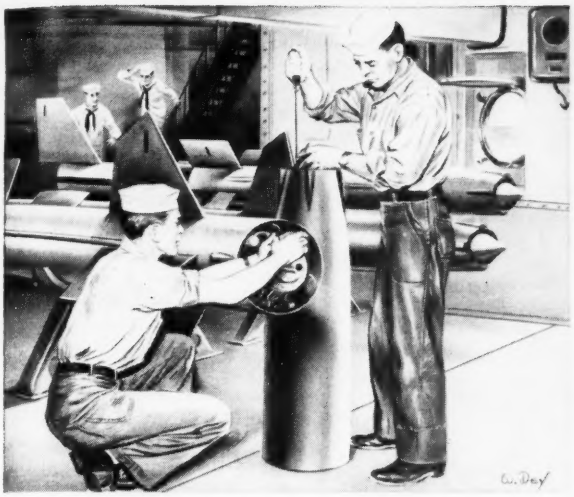
ARPA Forms Anti-Missile Group

The Advanced Research Projects Agency has formed a Ballistic Missile Defense Group consisting of nine panels to work on anti-missile projects. Named as chairmen, their panels and former affiliations are: Ward C. Low, upper atmospheric physics, (Sylvania), David Luck, very early warning, (Radio Corp. of America); Glen Pippert, instrumentation and special ranges, (Lincoln Labs); Wade Blocker, destruction mechanisms, (Ramo-Wooldridge); Leroy Tillotson, anti-satellite, (Bell Telephone Labs); Richard Holbrook, active defense, (Rand Corp.); Clifford Cummings, interception, (Jet Propulsion Lab); Stewart Hight, data processing for decisions) (Sandia Corp.); and Harry Iddings, radar, (GE).

Thor-Able Blasts Off



Carrying a mouse in its nose cone, AF Thor-Able vehicle heaves itself toward space at the beginning of a successful 6000-mile nose cone re-entry test.



MISSILE COMPONENTS Bulova safety and arming systems protect ground, air and sea crews from load to launch, then take over in flight. Safety factor of one in a million is specified and reliably delivered by Bulova's precision production facilities. Powder-driven gyros and fuzing systems are among other Bulova developments for 18 key missiles.

AIRCRAFT INSTRUMENTS Bulova's new Servo Altimeter assures maximum reliability through unprecedented sensitivity, accuracy and repeatability. At 40,000 feet, it detects 4-foot changes . . . is correct to 40 feet. Safety is improved in traffic control and flight over difficult terrain. As a control instrument, it is readily adaptable to guided missiles.

Bulova reliability helps to solve today's most challenging problems

For more than 80 years, Bulova has charted new courses in the area of reliability.

Milestones along the way are the electronic and electro-mechanical devices created by the Bulova capability—the uncommon blend of pioneering vision and precision production experience.

These Bulova developments, distinguished by their advanced design and consistent high performance, help our nation's defense and industry stake solid claims on the frontiers of science and space.

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INFRA-RED COMPONENTS Bulova infra-red cells are designed to unerringly guide Sidewinders to target. Bulova-improved production processes increase yield and product reliability. Other infra-red developments include filters, reticles and thermistor bolometers, as well as advanced research in mosaic and lead selenide cells.

PHOTOGRAPHIC SYSTEMS Bulova's new high performance 70mm recon-camera features 8 frame/sec. and pulse operation . . . vibration-free exposures to 1/4000 sec. From the smallest 16mm gun camera ever built to units of 9x18" format size, Bulova developments include optical, data recording and instrumentation, and special sequence cameras.

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The Mechanical Division of General Mills, Minneapolis, Minnesota, needs senior level staff personnel for creative design and development in the following fields:

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Positions available for *purely technical* and for *technical-supervisory* work—job titles and salary provide *equal* opportunity for advancement in both.

Positions exist in Engineering Department which is engaged in advanced design and development of military weapons and reconnaissance systems, communications, controls, guidance, navigation, and special purpose digital computers. Work is mainly military, with some special commercial instrumentation and control.

If you have at least five years' experience in creative design or development—a good understanding of fundamentals and ability to apply them—learn more about the opportunity and long range security offered at General Mills. You'll like our people, our interesting, nonroutine projects—and you'll like Minnesota, land of lakes and pine. In Minnesota everyone takes time to enjoy life.

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MECHANICAL DIVISION General Mills

Personnel Department (A2)

2003 E. Hennepin, Minneapolis 13, Minnesota

Dark Horse in Propellant Race

(CONTINUED FROM PAGE 35)

tages of such a monopropellant in comparison with solid and bipropellant systems. First, in comparison with solids:

1. It has an appreciably higher specific impulse than a solid at comparable chamber pressures.
2. Since regenerative cooling is possible, the burning time can be made as long as desired.
3. Throttling, cutoff and thrust programming are easily accomplished, and the optimum acceleration for each flight stage can be readily programmed.
4. Vehicle control is possible with a gimbaled thrust chamber.
5. CG control is easy without the use of an awkward blast tube, which is likely to burn out and is sure to reduce performance.
6. It is indifferent to storage and handling conditions. It will not crack when too cold, or in transit or when dropped, and the burning rate does not vary appreciably with propellant temperature.
7. It is always completely homogeneous, unlike a composite solid, in which uniform distribution of the oxidizer throughout the fuel matrix is not always achieved.
8. Finally, it is likely to be cheaper than a solid, and, if the missile is too large for prepackaging, the propellant can be easily shipped separately.

In contrast with the usual bipropellant system, the new monopropellant system offers these advantages:

1. It needs much less plumbing—only about half as much—and requires only one propellant tank.
2. It can easily be prepackaged, and will keep indefinitely without corrosion or stability problems.
3. It needs *no* mixture-control apparatus. Consequently there can never be any outage, or unintentionally unconsumed propellant.
4. It uses a much simpler and cheaper injector, since mixing problems do not exist. Much combustion instability has been traced to incomplete mixing of fuel and oxidizer.
5. *All* of the propellant can be used for regenerative cooling.
6. It offers greatly improved reliability, owing to reduction in the number of components.

These are some of the general advantages of such monopropellants—advantages independent of missile design and size.

A small missile—for instance, the garden-variety ground-to-air kind—could be designed to be as ready to go as a solid. Its powerplant would not require a single solenoid valve, and it would be fired simply by closing one switch. No propellant servicing and replacement would be needed; the tank would be loaded at the factory and would be ready from then on.

In a large missile like an IRBM, such a monopropellant would avoid problems of casting and shipping large solid grains, and would drastically reduce count down time as compared with a bipropellant liquid system. What's more, there wouldn't be any more need to worry about oxygen valves and boil-off. This is important, because it has been calculated that, in an IRBM missile, a monopropellant with an Isp of 215 sec is competitive with a bipropellant with an Isp of 250, all because of the simplification of the hardware and the elimination of the outage.

The possibilities of such monopropellants for missile design are rather obvious. Monopropellants now in an advanced stage of development will make it possible to design a missile which combines the readiness and almost the simplicity of a solid rocket with the flexibility and performance of a bipropellant rocket.

The solids and the bipropellants seem to be racing neck-and-neck. A look over the shoulder would show there's a third horse in this race which is coming up fast.

Brooklyn Poly Offers M.Sc. In Space Technology

Polytechnic Institute of Brooklyn will inaugurate a new curriculum leading to a M.Sc. degree in astronautics or space technology this month. The program will require 34 graduate credits, two more than is normally required for the degree. Courses will include minimal principles of structural analysis, advanced calculus, viscous compressible flow, supersonic flow, hypersonic flow, mechanics and thermodynamics of real gases, dynamics, space mechanics, guidance and control, a seminar and a graduate thesis. Antonio Ferri, head of the Aeronautical Engineering Dept., which jointly developed the project with the Electrical Engineering Dept., noted that the program is designed to grow into a doctoral curriculum as the state of the field advances.

Atom-Plane Research

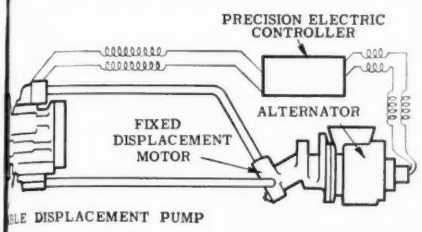
A nuclear reactor for research on an atomic airplane engine has been ordered built by the AEC near Sandusky, Ohio. Target date for completion is January, 1960.

New VICKERS building block concept applied to

CONSTANT SPEED DRIVES

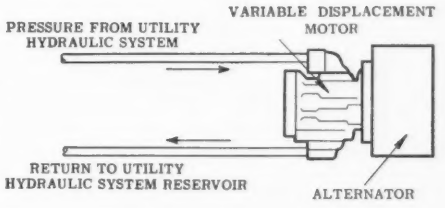
for 400 cycle A.C. electrical systems

1. Unlimited Versatility
2. High Efficiency
3. Fast Delivery
4. Low Cost



Frequency control ± 0.1%. Uses electronic frequency controller to regulate pump displacement. System pressure is function of load.

Frequency control ±0.25%. Uses load sensitive system to match infinitely variable electrical load. System pressure is constant, flow demand is load dependent.



• Using this "building block" construction, Vickers Constant Speed Drives are assembled to exact requirements from the abundance of Vickers standard and proven components. Practically any characteristics you need can be quickly adapted to the existing Vickers product mix. These include:

FREQUENCY CONTROL

± 3% with hydraulic control
± 0.1% with electronic control (or better if desired)

VERSATILITY

1 to 75 hp with standard hardware
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HIGH EFFICIENCY

Volumetric efficiency of either pumps or hydraulic motors is 96% at 3000 psi. This together with optimum matching of components results in very high system overall efficiency.

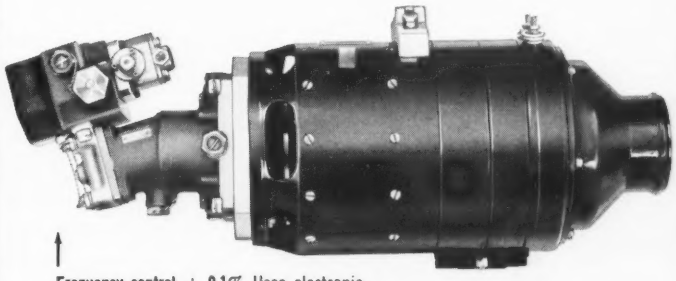
MINIMUM WEIGHT

Significant optimization engineering can be applied to your system design considerations from similar Vickers application experience.

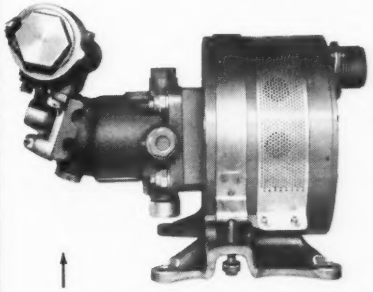
OVERLOAD CAPACITY

Depending upon system requirements, overload capacity of from 120% to 200% can be provided.

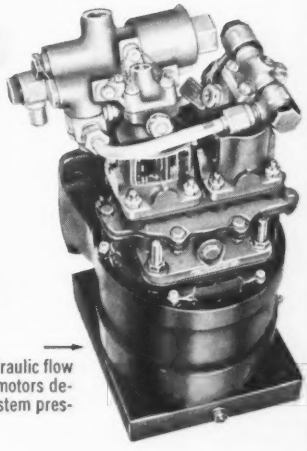
For further information, write for Bulletin SE-100.



Frequency control ± 0.1%. Uses electronic frequency signal to trim hydraulic flow control. System pressure is constant.



Frequency control ± 3%. Uses hydraulic flow control only. System pressure is constant.



Frequency control ± 3%. Uses hydraulic flow control to supply single or dual motors depending upon load variations. System pressure is constant.

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Government contract awards

AF Million-Lb Thrust Engine Contract Goes to Rocketdyne

Wright Air Development Center has awarded Rocketdyne a contract to begin development of a million-lb thrust liquid rocket engine for the Air Force. Amount of the contract was not disclosed. At the same time, Rocketdyne received an extension of an AF contract to develop a previously undisclosed liquid engine with thrust in the intermediate range between current propulsion systems and the million-lb engine.

Program manager for both the intermediate and million-lb engines, designated E-1 and F-1 by Rocketdyne, will be D. E. Aldrich.

AF to Pay $314.8 Million To Convair for Atlas Work

The Air Force has announced definitization of a letter contract totaling $314.8 million to Convair for past and present research, development and design of the Atlas ICBM and supporting equipment.

GE Gets $12 Million Job For Long-Range Radar Systems

The Air Material Command's Rome (N.Y.) Air Force Depot has awarded General Electric a $12 million contract for production of a new advanced long-range search radar system, designated AN/FPS-7, developed by ARDC's Rome Air Development Center.

Navy Extends Martin Nuclear Seaplane Studies

A Navy contract in excess of $385,000 has been awarded The Martin Co. to extend engineering studies on a nuclear seaplane project, which covers powerplant requirements, airframe designs, and nuclear reactor shielding techniques.

Talos Contracts to Bendix

Navy BuOrd has awarded Bendix Aviation production and engineering contracts for Talos missiles totaling $21.5 and $7.5 million, respectively.

Atlas Support Equipment

Consolidated Electrodynamics has received contracts totaling $1.5 million from Convair's Astronautics Div. for design, development and production of Atlas ground support equipment.

Thor Air Conditioning Units

Douglas Aircraft has let a contract in excess of $2 million for all-purpose air conditioning units for support of the Thor missile to C. G. Hokanson Co.

Missile Radar Beacons

An AF contract for development of an advanced superheterodyne-type radar beacon to be installed on long-range ballistic missiles for WS-107 and WS-315 has been let to the Motorola Western Military Electronics Center in the amount of $651,151.

Explorer Tracking Stations

Siegler Corp. has been awarded two Army contracts totaling $500,000 for construction of three tracking stations for Explorer. The company also received a $300,000 contract to produce components for the Nike-Hercules launching system.

Propellants Study

Budd Co. has received a contract from Thiokol for research and evaluation of the best method for nondestructive testing of solid propellants for missile application.

Photo Reconnaissance Study

Cornell Aeronautical Laboratory will investigate ways to advance techniques of photographic reconnaissance from space vehicles under a $200,000 AF contract.

Tracking Antennas

Missile and satellite tracking antennas, 85 ft in diam, have been ordered by the government from Blaw-Knox, which will design, fabricate and install them.

VTOL Jet Control System

Ryan Aeronautical is developing a jet reaction control system that can function efficiently with an afterburner in a tactical type vertical takeoff and landing plane under a Navy contract awarded to the company recently.

Atlas Component Systems

A million dollar development contract for Atlas ICBM component systems has been awarded to The Garrett Corp. by Convair, prime contractor on the Atlas.

SYNOPSIS OF AWARDS

The following synopsis of government contracts awards lists formally advertised and negotiated unclassified contracts in excess of $25,000 for each Air Force, Army and Navy contracting office:

AIR FORCE

Commander, Hq, AMC, Wright-Patterson AFB, Ohio

Sled test program for canopy and interim seat ejection for model F-106B aircraft, $1,067,772, **Convair,** 3165 Pacific Highway, San Diego, Calif.

Phase I development program, B-70 weapon system, $3,440,000, **North American Aviation,** International Airport, Los Angeles 45, Calif.

Development of nonmetallic tooling for high-temperature applications beyond the temperature capabilities of plastics and epoxy resins (600–1500 F), which will be inexpensive and cure in a short time, $192,391, **Georgia Div. of Lockheed Aircraft,** Marietta, Ga.

High-temperature jet fuel, hydrocarbon, to be used in full-scale engines and small-scale tests to determine its suitability as an aviation fuel, $41,000, **Phillips Petroleum,** Bartlesville, Okla.; $40,499, **Union Carbide Olefins Co.,** Union Carbide Corp., 30 E. 42 St., New York 17, N.Y.; $26,760, **Southwest Research Institute,** 8500 Culebra Rd., San Antonio, Tex.

Hq, AFCRC, ARDC, Laurence G. Hanscom Field, Bedford, Mass.

Research directed toward an integrated data handling subsystem, $63,503, **Hycon Eastern, Inc.,** 75 Cambridge Parkway, Cambridge, Mass.

Research directed toward design and development of transistorized amplifiers for balloon carriers, $28,219, **Transistor Applications, Inc.,** 50 Broad St., Boston, Mass.

Research on the theory of the motion of artificial satellites, $35,000, **Yale Univ.,** New Haven, Conn.

Design and construction of radiosonde data converter, $81,484, **Tasker Instruments Corp.,** 3549 Cahuenga Blvd., Hollywood 28, Calif.

Design and construction of a luminous shock tube for quantitative high-temperature spectrographic investigations of basic parameters, $35,000, **Ohio State Univ. Research Foundation,** Columbus 10, Ohio.

Investigation of applicability of solar energy conversion for electrical power supply of high-altitude balloon-borne equipment, $52,158, **Hoffman Laboratories Div.,** Hoffman Electronics Corp., P.O. Box No. 2471, Los Angeles 54, Calif.

Investigations of various activator-refractory substrata combinations, $49,648, **General Electric,** 1 River Rd., Schenectady, N.Y.

Investigation of low-noise amplifier, ferromagnetic amplifier and traveling wave type amplifier, $79,858, **Motorola, Inc.,** 5005 E. McDowell Rd., Phoenix, Ariz.

Optical system to be incorporated in satellite tracking camera, $98,700, **Perkin Elmer Corp.,** Main Ave., Norwalk, Conn.

Satellite tracking camera, $195,000, **Boller and Chivens, Inc.,** and **Joseph Nunn and Assoc.,** 916 Meridian Ave., S. Pasadena, Calif.

Studies, testing and services in connection with rockets, $112,861, **Aerojet-General,** 6352 N. Irwindale Ave., Azusa, Calif.

Theoretical and exploratory experimental research in electromagnetic networks and related solid state and plasma topics, $225,000, **Polytechnic Institute of Brooklyn,** 99 Livingston St., Brooklyn 1, N.Y.

Design and analysis of high-speed computer circuits, $186,000, **International Business Machines Corp.,** Poughkeepsie, N. Y.

Hq, AF Missile Test Center, ARDC, Patrick AFB, Fla.

Elevated balloon telemetry antenna system, $75,835, **Dynatronics, Inc.,** 717 W. Amelia Ave., Orlando, Fla.

Service-test transponders and ancillary equipment and data, $300,000, **Convair-Astronautics,** San Diego 11, Calif.

Rocket propellant, $74,480, **Westvaco Chlor-Alkali Div.,** Food Machinery and Chemical Corp., 161 E. 42nd St., New York 17, N.Y.

Hq, AFOSR, ARDC, Washington 25, D.C.

Research on boron and silicon chemistry, $30,000, **Univ. of Washington,** Seattle, Wash.

Continuation of research on diffusion in metals, $25,000, **Univ. of Illinois,** Urbana, Ill.

Continuation of research on gas-phase and surface reactions of hydrocarbons at moderately high temperatures, $74,502, **Univ. of Texas,** Austin 12, Tex.

Research on aerothermoelasticity, $48,550, **MIT,** Cambridge 39, Mass.

Research on optical and electrical properties of solids, $245,060, **Univ. of Rochester,** Rochester, N.Y.

Continuation of research on electromagnetic theory and information processes, $100,000, **Polytechnic Inst. of Brooklyn,** Brooklyn 1, N.Y.

Research on combustion aerodynamics, $78,144, **Harvard College,** Cambridge, Mass.

Study of hypervelocity particle effects, $135,549, **Aeronautic Systems, Inc.,** 1234 Air Way, Glendale, Calif.

Research program on rational scaling procedures for liquid-fuel rocket engines, $41,969, **Sunstrand Turbo,** A Div. of Sunstrand Machine Tool Co., 10445 Glenoaks Blvd., Pacoima, Calif.

Basic studies in magnetohydrodynamics, $151,011, **Avco Mfg. Corp.,** Avco Research Lab Div., 2385 Revere Beach Parkway, Everett 49, Mass.

Research on heat transfer characteristics of diffusion boundary layers, $107,350, **MIT,** Cambridge 39, Mass.

Research on ignition of solid propellants, $87,598, **Princeton Univ.,** Princeton, N.J.

Research on reports concerning research on intermittent and nonlinear processes in turbulent flows, $37,700, **Univ. of Maryland,** College Park, Md.

Research on combustion processes in liquid-propellant rocket engines, $242,550, **Princeton Univ.,** Princeton, N.J.

Investigation of the effects of very high pressure and temperature on semiconducting and insulating materials, $40,000, **Battelle Memorial Institute,** Columbus, Ohio.

Effect of diffusing gas on aerodynamic heating, $51,600, **MIT,** Cambridge 39, Mass.

Research on diffusion in semiconductors and related problems, $40,000, **Univ. of Illinois,** Urbana, Ill.

Hq, Rome Air Force Depot, USAF, Griffis AFB, N.Y.

Radomes, $691,305, **Parsons Corp.,** P.O. Box 112, Traverse City, Mich.

ARMY

Boston Ordnance District, Army Base, Boston 10, Mass.

Warhead, guided missile, inert, XM-15, $42,600, **The Hicks Corp.,** 1671 Hyde Park Ave., Boston 36, Mass.

Pittsburgh Ordnance Dist., 200 Fourth Ave., Pittsburgh 22, Pa.

Research and development study of electromagnetic wave propagation in rocket exhausts, $70,000, **Pennsylvania State Univ.,** University Park, Pa.

Purchasing and Contracting Div., White Sands Missile Range, N. Mex.

Targets, Pogo-Hi, $229,880, **American Machine and Foundry Co.,** Buffalo, N.Y.

Digital data recorder, $116,000, **Wayne George Corp.,** Boston, Mass.

San Francisco Ordnance Dist., 1515 Clay St., P.O. Box 1829, Oakland 12, Calif.

Target drone missiles system XQ5 and related services, $2,500,000, **Lockheed Aircraft,** Sunnyvale, Calif.

U.S. Army Ordnance Dist., Los Angeles, 55 S. Grand Ave., Pasadena, Calif.

Depot replenishment repair parts for the Corporal missile system, $189,928, **Gilfillan Bros. Inc.,** 1815 Venice Blvd., Los Angeles, Calif.

Replenishment repair parts for guided missile, artillery, M2 and related ground handling equipment, $163,000, **Firestone Tire & Rubber Co.,** 2525 Firestone Blvd., Los Angeles 54, Calif.

Dart, antitank, guided missile, $99,230, **Aerophysics Development Corp.,** Box 689, Santa Barbara, Calif.

Repair parts for Nike system, $68,900, **Douglas Aircraft,** 3000 Ocean Park Blvd., Santa Monica, Calif.

Supplies and services relating to Honest John missile, $706,316, **Douglas Aircraft,** 3000 Ocean Park Blvd., Santa Monica, Calif.

Warhead testers, $38,147, **Telecomputing Corp.,** 12838 Saticoy St., N. Hollywood, Calif.

Transponders, $51,062, **Aerophysics Development Corp.,** P.O. Box 689, Santa Barbara, Calif.

Microlock test receivers, $43,066, **Hallamore Electronics,** 8352 Brookhurst Ave., Anaheim, Calif.

(CONTINUED ON PAGE 98)

SENIOR STAFF OPENINGS IN BASIC RESEARCH

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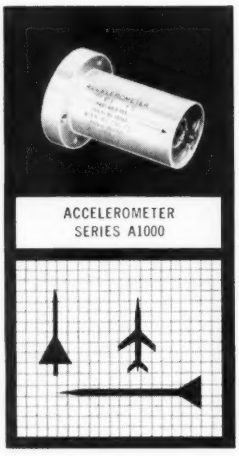

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Missile Market

(CONTINUED FROM PAGE 50)

ness, and no financing is expected on top of the $3.4 million raised last year from a convertible debenture issue.

In April, 1957, Emerson acquired Pryne & Co., (based in California) for stock, thus adding $5 million in sales from products complementary to its own line and strengthening its sales force in a strategic area.

To summarize, all indications seem to point to a continuation of sound growth, both in commercial business and in missile and military work. With improving profit margins as an additional impetus, net earnings are expected to show even greater gains. As the market does not yet seem to recognize fully Emerson's excellent potential and strong participation in the missile program, opportunities for long-term capital appreciation seem to far outweigh the risks for the investor at this time.

The company's 690,000 shares of common stock are traded on the New York Stock Exchange, with about 25 per cent of the stock closely held.

Acoustica Associates, Inc., on the other hand, has a very short past as a base for its most promising future. Founded in 1955 to produce ultrasonic devices (a brand new field), it recorded sales of $34,000 in its first year of operation. Sales jumped 1000 per cent in fiscal '57 and 300 per cent in fiscal '58, while a further 300 per cent increase, to the $3 million level, is projected for the current year. Indications also are that this year will bring the company its first real earnings, although it did manage to report 6¢ a share in fiscal '58 and only has an earned surplus deficit of $15,000 left to wipe out. This financial legerdemain has been accomplished by the unbeatable combination of a young and aggressive management successfully pushing acceptance of soundly conceived and developed products.

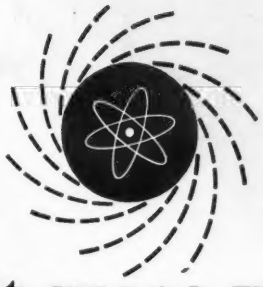
The extent of this acceptance is evidenced by the fact that Acoustica has the unique distinction of being the only small business firm holding a prime contract for a complete airborne system for the AF Atlas ICBM program. This production contract, which exceeds $1 million, is for airborne fuel control systems and related ground support equipment.

The Army is also a good customer, purchasing ultrasonic liquid-level sensing devices for its Redstone Arsenal to precisely determine the levels of fuels and propellants loaded in the missiles it produces there. The company also sells to prime contractors of other missile and high-performance aircraft programs.

Although the potential volume in this field alone is tremendous—working all the way through on the full Atlas program alone could mean $25 million in business—the company is by no means restricted to this market and has been actively developing its line of ultrasonic cleaning equipment. Having started with small equipment which could only be used to clean tiny precision-manufactured articles, Acoustica is today capable of delivering 40-ft long tanks holding several thousands of gallons of ultrasonically activated detergent or solvent solution. Rapid progress in the field has made virtually every major company in the U.S. a potential user of ultrasonic cleaning techniques, and the company's list of customers already reads like a Who's Who of American Industry.

Not satisfied with its rapid internal growth, Acoustica recently acquired General Ultrasonics Co., whose main area of activity has been ultrasonic emulsifying, plating, cleaning and degassing, thus further broadening Acoustica's product lines and markets. The company is continuing to look for other acquisitions.

Acoustica's 292,927 shares of common stock are traded on the over-the-counter market, with about 60 per cent of the stock held by officers, directors and other insiders.



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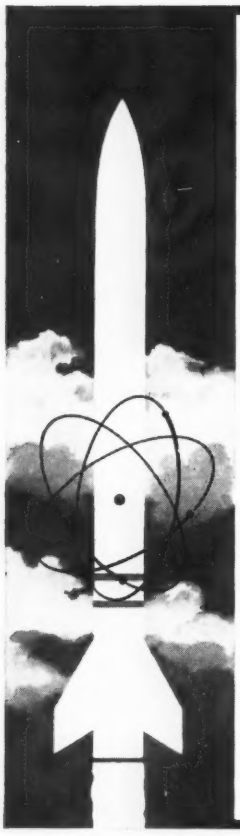

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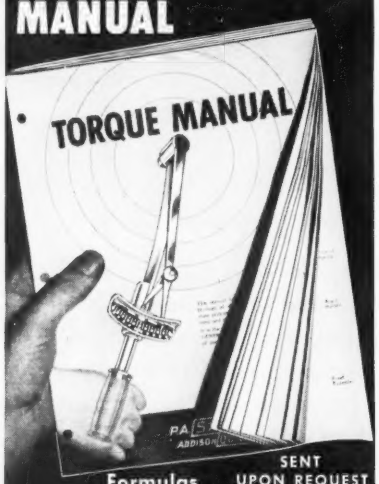

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Old Problems

(CONTINUED FROM PAGE 33)

formula, it's obvious that the rocket designer is after a propellant producing chamber gases with a high flame temperature and a low molecular weight.

Most advances in performance of solid propellants have been achieved by increasing flame temperature. However, with higher temperatures come greater problems of containing the hot rocket gases. At the present time, an all-out race between propellant and material development is underway. Those working for satisfactory chamber and nozzle materials are keeping up through tricks like film cooling, which destroys the simplicity of the rocket and lowers its reliability.

The design of all but end-burning charges requires a passage for gas from the forward to the aft end of the rocket. Grain designers would like to use this volume for propellant, i.e., make the passage as small as possible. However, restriction of the diameter of this internal port increases the pressure drop of the flowing gas and, in turn, the forces on the propellant.

Pressure drop as a function of the ratio of port area to rocket nozzle throat area is shown by the graph on page 33. The pressure drop within the channel can impose severe forces on the propellant. If it is soft, as required for case-bonding, excessive deformation may occur, causing restriction of the port or even propellant failure. Moreover, the burning of the propellant may be altered by the gas flow. Burning rate is a function of the velocity of gas across the surface of the solid and hence a function of port-to-throat ratio by some little understood mechanism.

Physical Properties

The physical properties of a solid propellant can be looked at in terms of strength and extensibility over the operating temperature range of the rocket. Consider a solid propellant case-bonded to a steel shell. The steel has a modulus of elasticity relatively independent of temperature. At the lowest operating temperature, the propellant must retain enough elasticity to stretch as the steel chamber expands under operating pressure. Extensibility of the propellant at the highest operating temperature is no problem. On the other hand, at high

temperatures, propellant strength deteriorates, and the propellant may no longer be capable of withstanding the acceleration and ballistic forces to which the grain is subjected.

Actually, there are many plastics which meet the requirements if operating temperature range is not too extreme. A problem arises when the plastic is loaded with solid materials, such as ammonium perchlorate and metals. These alter physical properties considerably, lowering the extensibility.

Simplicity Is Important

The greatest advantage of the solid-propellant rocket motor is simplicity. It consists of a chamber, a propellant grain and a nozzle. To keep his product simple, the solid rocket manufacturer prefers to design and manufacture propellant charges as one huge chunk. Now, extremely large rockets —weighing, say, 25,000 to 50,000 lb— introduce major handling and transportation problems.

This problem might be solved by breaking down a very large rocket into low-weight subassemblies. However, this adds to its complexity and cancels part of the advantage solid rockets have over liquid rockets.

In view of this, some consideration might be given to manufacturing solid rockets at the launching site, thus avoiding the problems of railroad-tunnel clearance, bridge loadings, etc. (*Editor's Note:* See page 38.) Although this system is feasible, and has been seriously considered by both propellant manufacturers and the military, there are disadvantages to on-site manufacture. For instance, quality control becomes a difficult problem, and the travel time of trained personnel cannot be ignored.

Another solution to the problem of extremely large rockets is that of clustering several large rockets to form a single propulsion unit. This technique has been used successfully in many test vehicles, and has been used or proposed for service use in several current missile development programs.

Finally, the thrust of a solid ballistic missile must be programmed either by the design of the surface characteristics of the propellant charge or by judicious variation of the propellant formulation in various areas of the charge. Dual-thrust rockets have been produced with initial high thrust which boosts the missile to cruising velocity and a lower thrust level which maintains the missile at cruising speed to the target.

The direction of flight of a ballistic missile is generally controlled through variation of the thrust vector, and thrust is terminated when the desired velocity vector is obtained. In solid-propellant rockets, thrust vector can be controlled through deflection of the jet by any of several techniques. There are also several techniques available for the instant termination of thrust upon command.

Solid vs. Liquid

To sum up, solid rockets can now be designed with performance and size competitive with liquid rockets. Thrust-vector control and thrust termination are currently being included in the designs of solid-propellant rockets, and some measure of thrust programming is being designed into them. While these add to the complexity of the solid rocket and reduce its inherent reliability, they do not affect its storability and ready service.

These factors, along with ease of scale-up to quite large sizes, have made solid-propellant rockets strong contenders for propulsion honors in large ballistic missiles.

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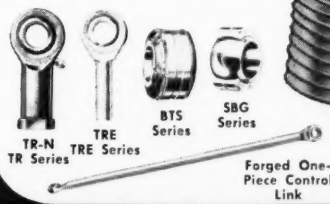

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Bourdon-Tube Transducer: Resolution of up to 400 wires is obtained with Model 461227 Bourdon-tube pressure transducer. Covering pressures from 200 to 10,000 psi (absolute, differential or gauge), this transducer is especially suitable for measuring noncorrosive liquid or gas pressure in airborne applications. G. M. Giannini & Co., Inc., Pasadena, Calif.

Missile Power Supply: Designed for missile test, checkout and launching applications, the Model M-1071 tubeless, magnetic-amplifier-regulated, d.c. source operates from a 115 v, 1 phase, 60 cycle, a.c. input. It provides d.c. output of 0 to 32 v up to 35 amp with a continuous duty rating of 25 amp. Output regulation accuracy is ± 1 per cent, and ripple is limited to 1 per cent RMS at 32 v and full load. Perkin Engineering Corp., 345 Kansas St., El Segundo, Calif.

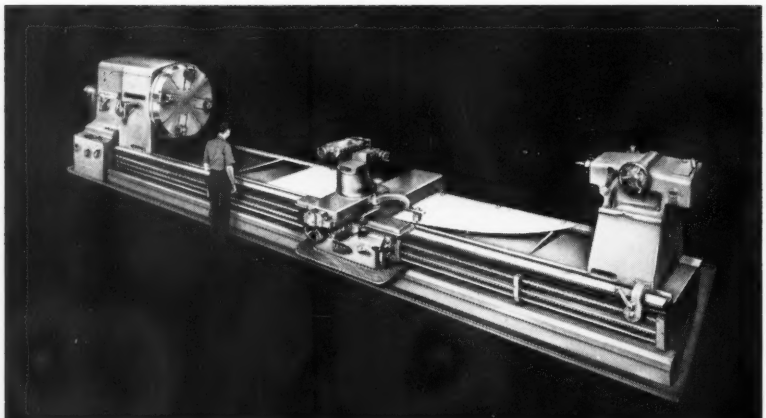
Direct-Reading Optical Gauge: An all-purpose inspection and quality control instrument, the DR-25 optical gauge measures depth, thickness, height and diameter. Measuring range is continuous from zero to 3 in., with no masters or set gauges needed. Measurements read on an illuminated, magnified scale, graduated in intervals of 0.0001 in., with an accuracy of 0.000025 in. Although the work table makes it easy to adapt special fixtures, most parts need merely be laid on the anvil for measurements to be made. A turn of the control knob lowers the spindle until it touches the part. The spindle stops automatically on contact. Bausch & Lomb Optical Co., Rochester, N.Y.

Miniaturized Switch: Designed for missiles, the sub-miniature "SX" snap-action switch measures only 0.5 x 0.35 x 0.2 in. (on the case) and weighs $^1/_{28}$ oz. The case, cover and plunger are high strength plastic; contacts are fine silver; and spring is beryllium-copper. Micro Switch Div. of Minneapolis-Honeywell Regulator Co., Freeport, Ill.

All-Weather Jet VTOL Cockpit: Engineers at Ryan Aeronautical Co. have developed a VTOL cockpit which makes all-weather instrument flight in jet aircraft possible. A mockup has been delivered to the Flight Controls Laboratory, WADC, Dayton, Ohio, for evaluation. Among innovations in the cockpit are vertical indicating instruments to provide quicker, clearer reading; a tiltable pilot's seat, which rotates through a 45-deg arc to provide comfort in adjusting to both horizontal and vertical attitudes; and "side stick" instead of center-stick control to increase pilot's freedom of movement.

Ryan jet VTOL cockpit is checked by Col. J. L. Martin, USAF, Chief of the Flight Controls Laboratory, WADC, and George Yingling, Chief of Operations at the Laboratory.

Pneumatic Selector Valve: Tactair Model 9801, a four-way, solenoid-operated, pneumatic selector valve with rapid operation over a wide range of operating pressures, was developed for use in rocket release systems. It is $2^1/_4$ in. thick, $4^3/_4$ in. high and $5^3/_8$ in. across the solenoids. Weight less than 1.9 lb.; operating pressure range, 500 to 3000 psi; normal pressure operation, 1250 psi.

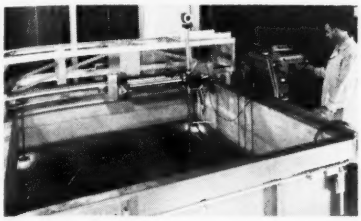


Diversey Expands

Diversey Engineering Co. of Franklin Park, Ill., has purchased the plant, equipment and assets of Warrior Tool and Engineering Co., Huntsville, Ala. This facility, expanded by 40,000 sq ft, will continue to machine and fabricate some of the largest missile components being made in this country.

Diversey also recently added to its equipment the largest tracer lathe in the country, the Missile Master, shown here. This lathe, especially designed to handle tough, high-strength alloys, will turn out nose sections, nozzles, motor cases, bulkheads, air-frame sections and hemispherical and elliptical domes.

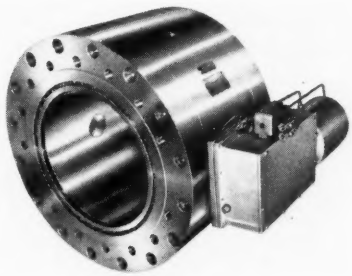
Tactair Valve Div., Aircraft Products Co., 300 Church Rd., Bridgeport, Pa.



Ultrasonic Test Facility: Avco is operating a special ultrasonic tank facility for immersion type nondestructive testing of the Titan ICBM reentry system. The 256-cu ft tank permits operation of a 7-ft stainless steel rotating table with adjustable scanning speeds of 12 to 200 in. per min. The turntable permits inspection of vertical, horizontal and azimuth dimensions. Avco Research and Advanced Development Div., 20 S. Union St., Lawrence, Mass.

"Ceramic-in-glass" electron tubes, employing principles of ceramic "stacked" tube for conventional glass bulb, give exceptional resistance to vibration, shock and fatigue. Two types are available—Type 7244, a dual triode for use as an oscillator, amplifier or mixer up to VHF, and Type 7245, a single triode for use as a grounded-grid amplifier in VHF equipment. Tubes are designed for application in very high velocity missiles and similar flight vehicles. Sylvania Electric Producers, Inc., Emporium, Pa.

Photo-Voltaic Cells: A series of silicon photo-voltaic cells, which have a response time of less than 20 microsec, has been developed for photoelectric devices. The cells are self-generating, requiring no external power supply, and operate through temperature variations from −65 to 175 C. Hoffman Electronics Corp., Semiconductor Div., 930 Pitner Ave., Evanston, Ill.



Zero-Leakage Ball Valve: Zero pressure drop is claimed for a new large capacity ball valve with a compact envelope. In operation, balanced ball design and seals provide sealing for liquid nitrogen at 320 F at 1200 psig, liquid oxygen at −297 F at 1000 psig, and helium at 70 to −320 F at 2100 psig. The valve also handles fuels and acids. The Vickery Co., 610 Sixteenth St., Oakland 12, Calif.

Explosive Disconnector: For severing umbilical cords and similar functions, Model 2011A disconnect converts a 55-circuit Bendix pygmy connector into a reusable explosive-actuated device. The explosive structure has threaded receptacles for two electrical primers. Beckman & Whitley, Inc., 1093 San Carlos Ave., San Carlos, Calif.

PRODUCT LITERATURE

Three-axis flight simulator for guidance and control systems. Aircraft Armaments Inc., Cockeysville, Md.

Relays for communications and computers. Cook Electric Co., 2700 N. Southport Ave., Chicago 14, Ill.

Products and systems in the fields of power supplies, actuators, blowers, timing devices and inverters. Western Design & Mfg. Corp. Div., U.S. Industries, Inc., Santa Barbara Airport, Goleta, Calif.

Blind rivets bulletin for aircraft and missiles. Deutsch Fastener Corp., P.O. Box 61072, Los Angeles 61, Calif.

Thermocouple accessories, Catalog G100-8. Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne and Windrim Avenues, Philadelphia 44, Pa.

Dynamic measuring instruments—accelerometers, high-temperature strain gauges and associated electronic equipment. Columbia Research Laboratories, MacDade Blvd. and Bullens Lane, Woodlyn, Pa.

Aluminum chart (Sec. G, No. 1). Government specifications and information on bending and forming sheet and plate. Peter A. Frasse & Co., Inc., 17 Grand St., New York 13, N.Y.

Titanium Minute Reader No. 3. Summary of facts on newest titanium alloys. Titanium Metals Corporation of America, 233 Broadway, New York 7, N.Y.

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Cold Propellants

(CONTINUED FROM PAGE 30)

in liquid nitrogen is another safety precaution, and one used in transporting liquid fluorine.

A great problem at an experimental laboratory or a launching site centers on how to deal with large quantities of spilled fluorine resulting from a system failure.

Hydrogen fluoride in the rocket exhaust also presents a problem, but one which can be handled by enclosures and water absorption. The illustration on page 29 shows a test facility at Lewis where the rocket exhaust is controlled by water quenching. Fifty thousand gallons of water per minute quench the rocket gases, absorb hydrogen fluoride, and then flow into a detention tank, where a calcium hydroxide treatment results in calcium fluoride, which can be hauled away and dumped.

Oxygen bifluoride is of somewhat less interest than fluorine. It is as toxic as fluorine, harder to make, and, as one would suspect, lies between oxygen and fluorine in performance. The handling and materials problems with oxygen bifluoride may be simpler than fluorine, but this has not been established. At liquid-nitrogen temperature, oxygen bifluoride has a density of 111 lb/cu ft as compared to 97 lb/cu ft for fluorine. This advantage disappears if both are used at their boiling points.

Hydrogen Is Best Fuel

Hydrogen is the best fuel or propulsion fluid for chemical, and nuclear, rockets because of its low molecular weight. Hydrogen is also an excellent regenerative coolant for the thrust chamber. The table at top right shows that, for an upper limit of 500 F, its heat-absorption capacity per pound is an order of magnitude greater than other fuels. While this advantage decreases when gas temperature and relative fuel proportions are considered, this does not detract from the attractiveness of hydrogen as a coolant.

The principal problems in using hydrogen arise from its very low boiling point, its very low density, and its very wide flammability limits in air or oxygen. The low boiling point requires special liquefaction, storage, transportation and line-transfer equipment. Much work in these areas has been done by the Bureau of Standards, Cambridge Corp., H. L. Johnston and others.

The very low density of hydrogen places a premium on lightweight

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DYNAMICIST. Advanced degree, applied mathematics background, and experience in missile stability analysis desirable. Work involves re-entry dynamics of advanced vehicles and dynamic analysis of space craft.

ENGINEER or PHYSICIST. With experience in the use of scientific instruments for making physical measurement. Work related to flight test and facility instrumentation. Advanced degree desired with minimum of 3 years of related experience.

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Heat-Absorption Capacity of Fuels

Fuel	Temperature range (Deg F)	Heat absorption capacity (Btu/lb)
Hydrogen	—420 to 500	3280
Hydrazine	70 to 500	348
Kerosene	70 to 500	253

tanks for its use in missiles and space craft. Along with these tanks will be associated problems of filling them, keeping the loss rate to a reasonable amount and prevention of hydrogen leakage. Liquid hydrogen tanks for space propulsion, moreover, must be well shielded from radiation of the sun, earth and other bodies to minimize loss.

Another class of cryogenics of great potential for rocket propulsion are free radicals, or molecular fragments, such as H, NH, N, CH and BH, which normally exist for only a few thousandths of a second but may be preserved by techniques involving temperatures near absolute-zero. These fragments are of interest because in recombination they release large quantities of energy and give specific impulses well above those of molecular chemical reactions. This subject has been amply covered in recent articles. (See, for example, August, 1957 and January, 1958, ASTRONAUTICS.) The Bureau of Standards has a team of scientists under Herbert Broida studying free radical chemistry.

In conclusion, the case for cryogenic propellants rests with their high performance potential. It can be shown that, as the propulsion requirement becomes more difficult, such as that needed for the larger payloads involved in satellite, moon or Mars missions, the need for high-energy propellants grows accordingly.

This all-important consideration justifies an all-out effort on solving the problems associated with using high-energy cryogenics in space craft.

Bath for Atlas

To prevent local "hot spot" corrosion while the Atlas is speeding through the atmosphere and eliminate unwanted weight of possible residues, the AF Missile Test Center at Cape Canaveral has taken to washing down the ICBM and other satellite launching stages with de-ionized water prior to countdown. Rohm & Haas provides the Amberlite resins used in six ion exchange units located near the launching pad.

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Contract Awards

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Study reports for drop test of Jupiter nose cone, $44,000, **Aerophysics Development Corp.**, P.O. Box 689, Santa Barbara, Calif.

Study and design for a new missile systems test facilities for solid propellants, $114,727, **Aerojet-General**, Azusa, Calif.

Design, procurement, fabrication and installation of instrumentation and control system in ABMA test facility area, $296,937, **Aerojet-General**, Azusa, Calif.

Nike field change kits, flat-bed missile booster transporter and launching area items, $1,214,067, **Douglas Aircraft**, 3000 Ocean Park Blvd., Santa Monica, Calif.

Engineering services related to Corporal missile system, $170,000, **Firestone Tire & Rubber Co.**, 2525 Firestone Blvd., Los Angeles, Calif.

Engineering services related to Corporal missile system, $185,134, **Gilfillan Bros., Inc.**, 1815 Venice Blvd., Los Angeles 6, Calif.

Guided missile, surface-to-surafce, $2,083,215, **Firestone Tire & Rubber Co.**, 2525 Firestone Blvd., Los Angeles, Calif.

Airborne telemetry and instrumentation packages, $91,695, **Gilfillan Bros. ,Inc.**, 1815 Venice Blvd., Los Angeles, Calif.

Launching area items, $33,923,649, **Douglas Aircraft**, 3000 Ocean Park Blvd., Santa Monica, Calif.

Supplies and services regarding missile targets, $2,380,808, **Radioplane Co.**, 8000 Woodley Ave., Van Nuys, Calif.

Nike warhead and fuze, $365,589, **Rheem Mfg. Co.**, 9236 E. Hall Rd., Downey, Calif.

Target drones, $720,921, **Radioplane Co.**, 8000 Woodley Ave., Van Nuys, Calif.

Propellant development, $81,935, **Grand Central Rocket Corp.**, P.O. Box 111, Redlands, Calif.

Hyperthermal research tunnel development and transport property measurements, $210,704, **Giannini Plasmadyne Corp.**, 18400 S. Main St., Santa Ana, Calif.

Engineering, research and development of guided missiles, free rockets, materials and wind tunnel operation, $5,148,500, **Cal Tech**, 1201 E. California St., Pasadena, Calif.

Airborne digital computing techniques study, $99,608, **North American Aviation**, 9150 E. Imperial Highway, Downey, Calif.

U.S. ARMY ORDNANCE MISSILE COMMAND, REDSTONE ARSENAL, Ala.

Engineering, design and drafting services necessary for design and development of rocket motors and launching, $35,000, **Barnes and Reinecke, Inc.**, 230 E. Ohio St., Chicago 11, Ill.

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DEPARTMENT OF THE NAVY, BUREAU OF AERONAUTICS, Washington 25, D.C.

Evaluation model drone tracking system, airborne and surface units, $253,994, **Motorola, Inc.**, Phoenix, Ariz.

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Aero-Astronautical Society Organized in Belgium

A new society dedicated to the promotion and advancement of the aeronautical and astronautical sciences has been organized in Belgium. Called "Association Belge des Ingénieurs de l'Aéronautique et de l'Astronautique" (ABITA), the society's 38 founding members represent all branches of the two sciences. Fraeys de Veubeke, professor, Liège and Louvain Universities, is chairman of the group.

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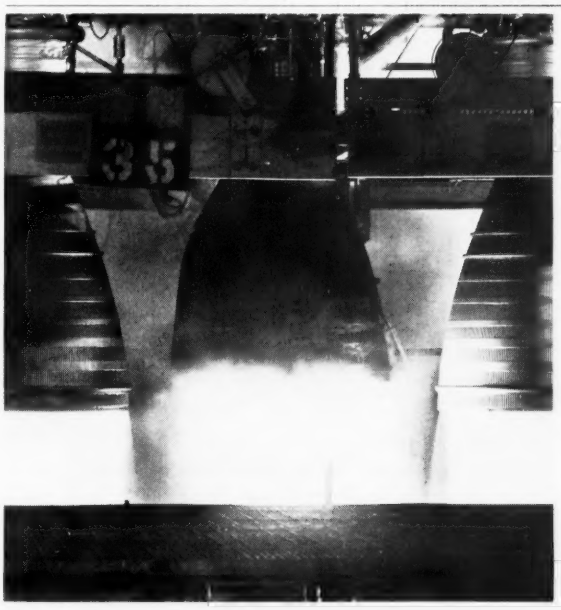

Atlas Shows Its Muscles

In first close-up to be released, Rocketdyne engines for Convair's Atlas ICBM roar in static firing. Shown are the gimbaled combustion chambers and nozzles of the two boosters (outside pair) and sustainer, which together develop about 350,000 lb of thrust. Atlas is currently undergoing long-range flight testing at Cape Canaveral.

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From the patent office

BY GEORGE F. McLAUGHLIN

Spontaneous Combustion of Furfural And Permanganate as Propellants

Spontaneous combustion may be obtained by contacting furfural with solid permanganates of many metals, and also with sufficiently concentrated permanganate solutions. Since permanganates in aqueous solution may be introduced conveniently into a reaction zone, those which have high solubility in water are preferred.

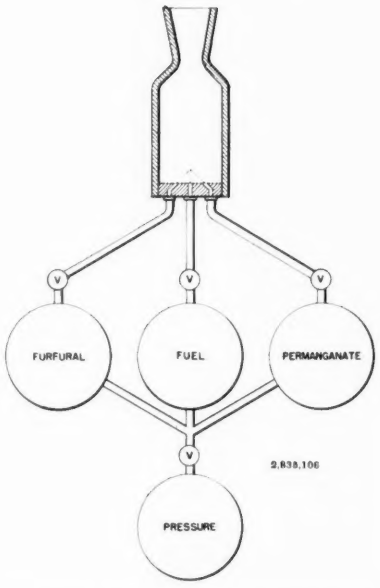
Permanganates which form solutions sufficiently strong to burn furfural spontaneously include those of calcium, aluminum, sodium, magnesium and barium. Others, including potassium permanganate, which are not sufficiently soluble in water, may be employed in the solid state, or, in some cases, as concentrated solutions in other solvents.

The manganese oxide and other metallic oxides formed through the spontaneous combustion of furfural and permanganates are, especially as freshly formed, active catalysts for other propellant reactions, including the combustion, with or without an additional oxidizer, of a variety of nitroparaffins. The invention contemplates the formation of manganese oxide in the combustion chamber through the reaction of furfural with a permanganate, and the catalysis of a principal gas-producing reaction—say, the combustion of a nitroparaffin—in the chamber by the oxide thus formed, and the use of predeposited solid permanganate in the chamber for the same purpose.

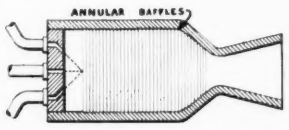
In motor operation, the outlet valves of the combustion chamber are set for proper flow rates of the furfural, permanganate and main propellant. The furfural and permanganate may be introduced simultaneously into the chamber in advance of the main propellant, so that the spontaneous combustion of the first two establish proper conditions for the ignition of the third.

The first figure shows the application of spontaneous combustion of furfural and a concentrated permanganate solution to initiate or sustain the decomposition of a main fuel or reactant in a jet engine.

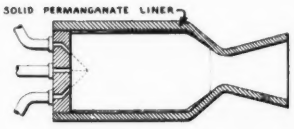
Injection of the main propellant may be omitted and the jet created by reaction of the furfural and permanganate alone. Preferred practice is to inject all three substances simultaneously, relying upon the reaction of the fufural and permanaganate to ignite the main propellant, which might be a self-combustible mixture of nitroethane and nitromethane.



Patented system for using spontaneous reaction of furfural and permanganate solution to initiate or sustain combustion of a main fuel.



Annular baffles on combustion-chamber wall can collect metallic oxides formed in the furfural-permanganate reaction to promote catalytic burning of main propellant.



Furfural can also react with solid charge of permanganate lining combustion chamber wall.

The catalytic effect may be prolonged and enhanced, especially if the supply of furfural and permanganate is interrupted after combustion of the main fuel is initiated, by providing means for catching and holding some of the oxides within the chamber. Normally, some of the oxides tend to accumulate on the chamber walls near the nozzle, and this effect can be enhanced by providing baffles or catching surfaces within the chamber.

A set of baffles, in the form of small annular serrations on the wall of the reaction chamber, interferes little with passage of the jet while providing surfaces for collection of solid oxides. Baffles are formed by cutting annular grooves around the inner periphery of the chamber, and in section appear as a series of saw teeth. In practice, it has been found that ordinary rough lathe markings serve to catch a catalytic layer adequate in many instances.

The second figure illustrates the use of baffles to collect and utilize for their catalytic action metallic oxides formed through reaction of converging streams of furfural and permanganate solution.

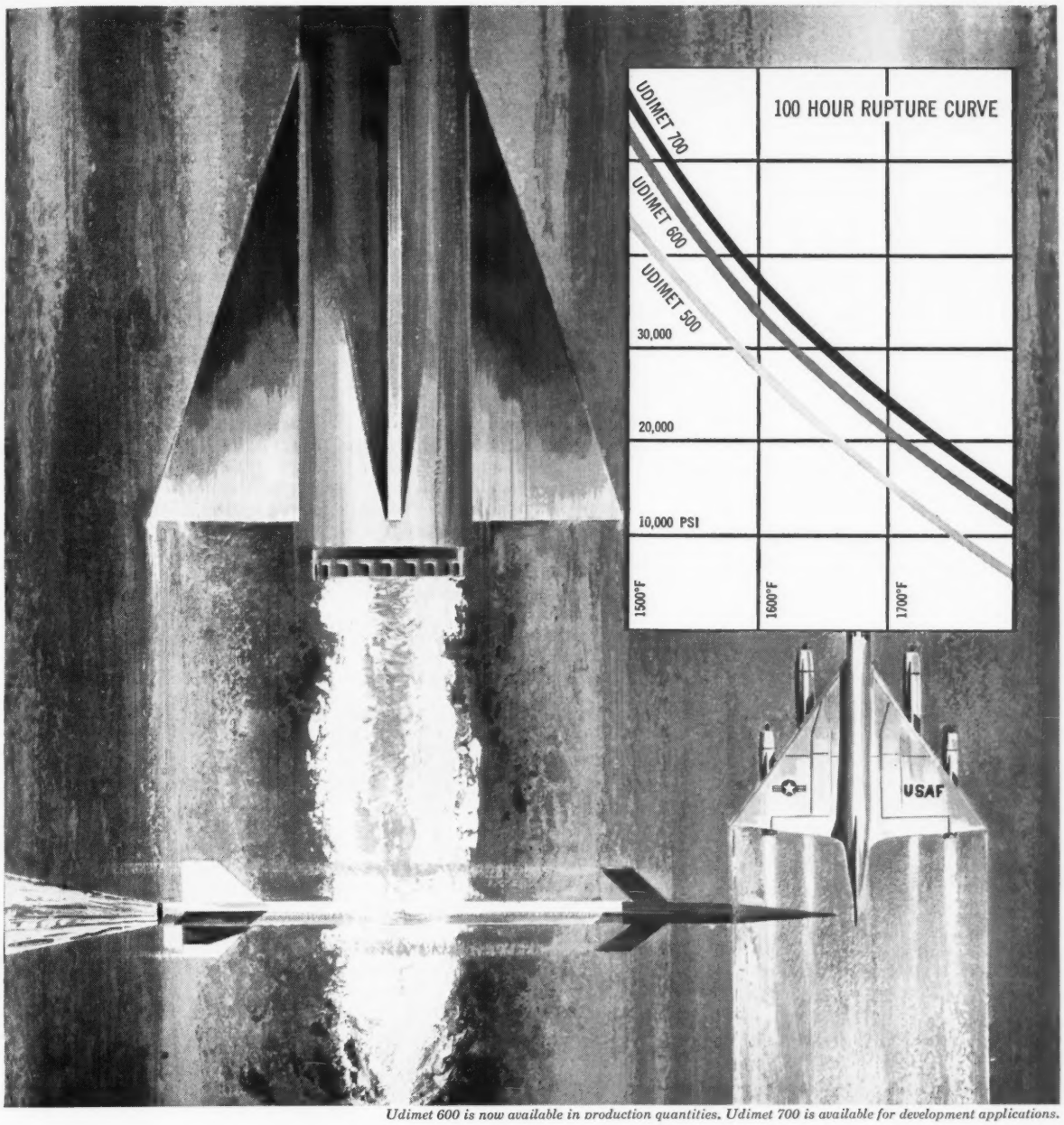
The third figure shows the use of a solid charge of permanganate disposed initially in the combustion chamber for reaction with a stream of furfural directed upon it.

Neither furfural nor permanganate is corrosive. They do not give off poisonous vapors, and both are relatively safe to handle.

Patent No. 2,835,106. Method of Jet Propulsion by Spontaneous Combustion of Furfural. James M. Carter (ARS member), Pasadena, Calif., assignor to Aerojet-General Corp. (ARS Corporate Member).

Method of Extinguishing Propellant Fires

Patent No. 2,837,891 was granted to Raymond R. Stasiak, Enon, Ohio, for a combination of chemicals for putting out rocket propellant fires. The process specifies reacting a fuel from the group, gasoline, xylidine, ethanol and furfuryl alcohol, with an oxidant, fuming nitric acid or liquid oxygen, and an extinguisher, dibromodifluoromethane or bromotrifluoromethane. The patent, applied for four years ago, has been assigned to the U.S. Air Force.



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In print

The Stars, by W. Kruse and W. Dieckvoss, translated by Ralph Menheim, The University of Michigan Press, Ann Arbor, 1957, 202 pp., illustrated. $5.

This tidy little (5 by $8^1/_2$ in.) volume, only a bit over half an inch in thickness, covers the principal known facts concerning the sidereal system. Not a single mathematical equation is introduced. Fundamental concepts, such as telescopic image formation, proper motion and stellar parallax, aberration of light, the period-luminosity law, and Hubble's velocity-distance relationship, are lucidly explained with the aid of about 60 diagrams.

Of special interest to the casual reader are the 45 photographs, of which about half have been contributed by the Hamburg Observatory. Something over 20 tables of interesting data (the brightest stars, nearest stars, largest proper motion stars, eclipsing variables, radial velocities, neighboring galaxies) make handy occasional reference material.

W. Dieckvoss and the late W. Kruse, who collaborated on "The Stars" while on the staff of the Hamburg Observatory, divide their volume into two main parts. Part One, entitled "Ways to the Stars," takes up problems of direction, brightness and color. Part Two, entitled "The World of the Stars," reviews our present knowledge of our own galaxy and the universe beyond.

As might be expected of a popular science text, no references are listed. This reviewer, however, was somewhat surprised that the name of no single astronomer was mentioned, not even the Hubble of the velocity-distance relation mentioned above.

The well-read layman will enjoy extending his horizon to the edges of space in this carefully designed little book.

Conrad D. Swanson
Army Ballistic Missile Agency

What's Going on in Space? By Commander David C. Holmes, U.S. Navy, Funk & Wagnalls Company, New York, 256 pp., illustrated. $3.95.

Described on its jacket as "a chronicle of man's exploration into space beyond this earth," this well-written book covers the entire story of space exploration, past, present, and future, in a well-informed and entertaining manner. Comdr. Holmes, a Naval Academy graduate, became a Naval aviator, and later has been associated with naval guided missiles programs. In addition, he is an amateur astronomer and a mystery story writer of note. He knows how to deal effectively with the English language.

The story of space flight has by now been told so thoroughly by so many writers, however, that almost anything an author can say sounds like an echo of other books one has already read on the subject. Comdr. Holmes does bring new sparkle to many parts of the story, particularly his accounts of incidents connected with experimental rocket aircraft, and descriptions of what the Russians said and did just before and after the first Sputnik. The book is also notable for the wealth of popularized science information the author has woven into it.

—G.E.P.

Behind the Sputniks, A Survey of Soviet Space Science, by F. J. Krieger, Public Affairs Press, 1958, 380 pp., illustrated. $6.

"Behind the Sputniks" presents a highly convincing demonstration that Russians of considerable stature have been seriously thinking and working on space travel problems for some years. Indeed, one of the most impressive things about this collection of Russian scientific papers on the subject of space travel is the sound practicality of the subject matter. The total volume of Russian literature on the subject far exceeds what can be published in a single volume. The problem was solved by careful selection and by including a long bibliography at the end of the book.

The book is an essential primer for those who would know the competition in the rapidly expanding field of space travel. It is a strong lesson to those who would not listen to, or believe, the continuing statements of the Russians themselves over the past years.

The only criticism of the book concerns a small publishing detail. It would have been far preferable to have listed the date and place of publication of the papers at the beginning of each paper. As it is, the reader is likely to assume that all of the included papers are Russian and forget that an occasional Western article is interspersed. The article entitled "Table of Soviet Missiles" is an illustration.

Otherwise, the book succeeds admirably in its purpose, stated in the preface:

"This work, as its title indicates, is a survey of Soviet astronautics based entirely on the open literature. It is by no means an exhaustive effort, for that would be an almost impossible task. Rather, it is a preliminary attempt at uncovering evidence of increasing Soviet concern with the challenging problems of space flight. What the Russians have written on the subject of astronautics provides important insights into their intent and aspirations in the conquest of outer space. Their technical literature clearly shows that their interest is not merely academic or superficial. It is as serious and purposeful as interest can be in a science that is sponsored to the hilt by a ruthless totalitarian regime."

—Eberhardt Rechtin
Jet Propulsion Laboratory

RECEIVED

Men, Rockets and Space Rats, New Revised Edition, by Lloyd Mallan (336 pages, Jullian Messner, New York, $5.95).

Basic Aeronautical Science and Principles of Flight, by Robert D. Blacker (242 pages, American Technical Society, Chicago, $5.95). Well-illustrated introduction to general aeronautics.

Satellites, Rockets and Outer Space, by Willy Ley (128 pages, New American Library of World Literature, New York, 35 cents). A Signet Key pocket book.

Basics of Digital Computers, by John S. Murphy (John F. Rider, New York). Fundamentals, in three paperbound volumes, at $2.50 per single volume, $6.95 per set (paperbound) or $7.95 for single volume, cloth bound edition. Profusely illustrated.

Metals for Supersonic Aircraft and Missiles, by the American Society for Metals (423 pages, American Society for Metals, Cleveland, $7.50). Compendium of technical articles and summaries, edited by D. W. Grobecker of Sandia Corp.; with index.

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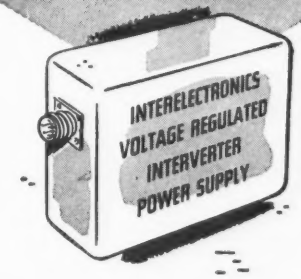

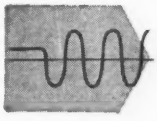

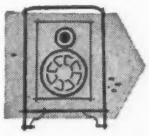

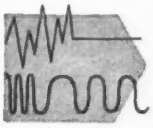

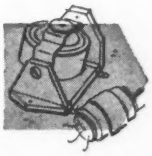

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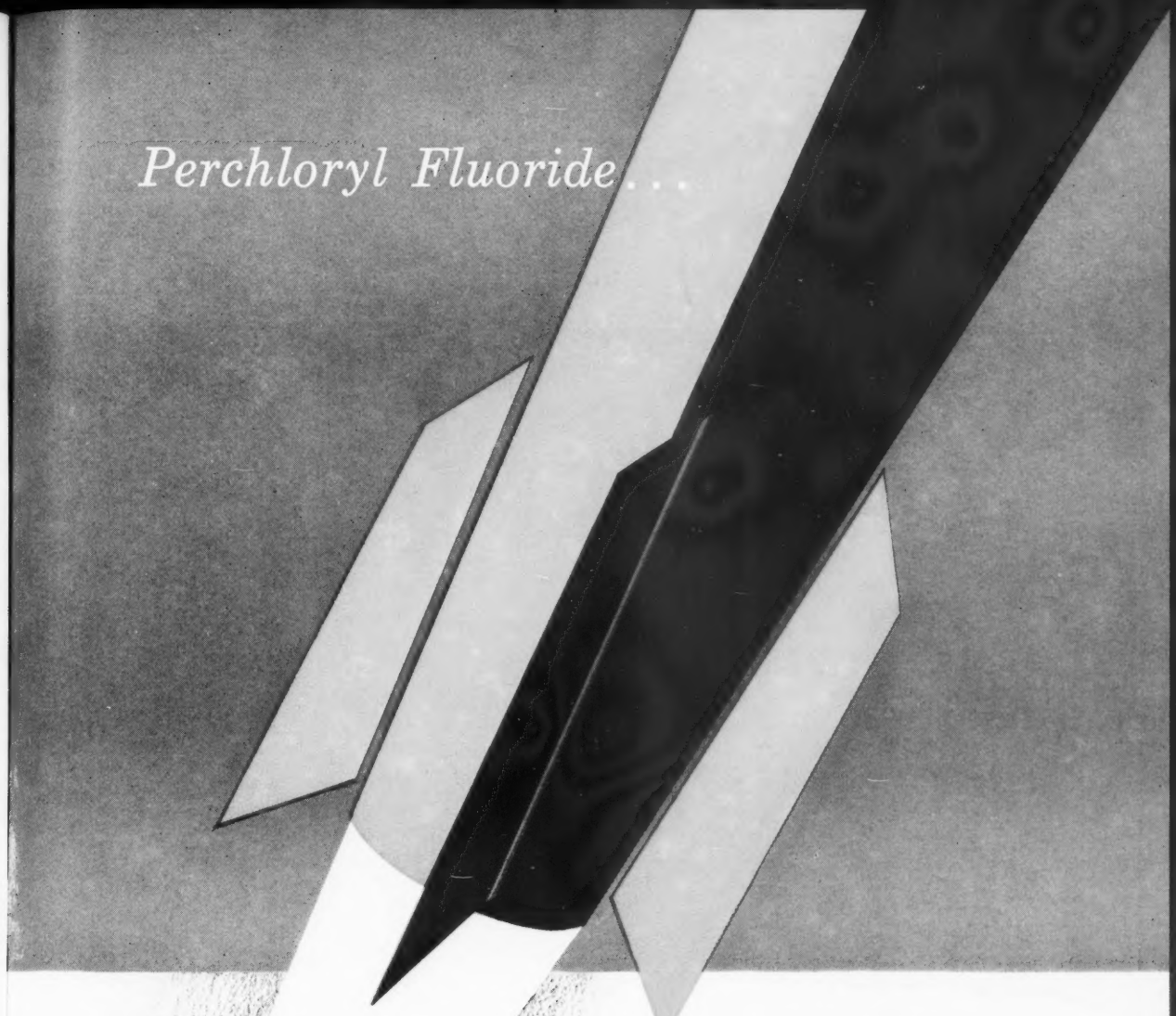

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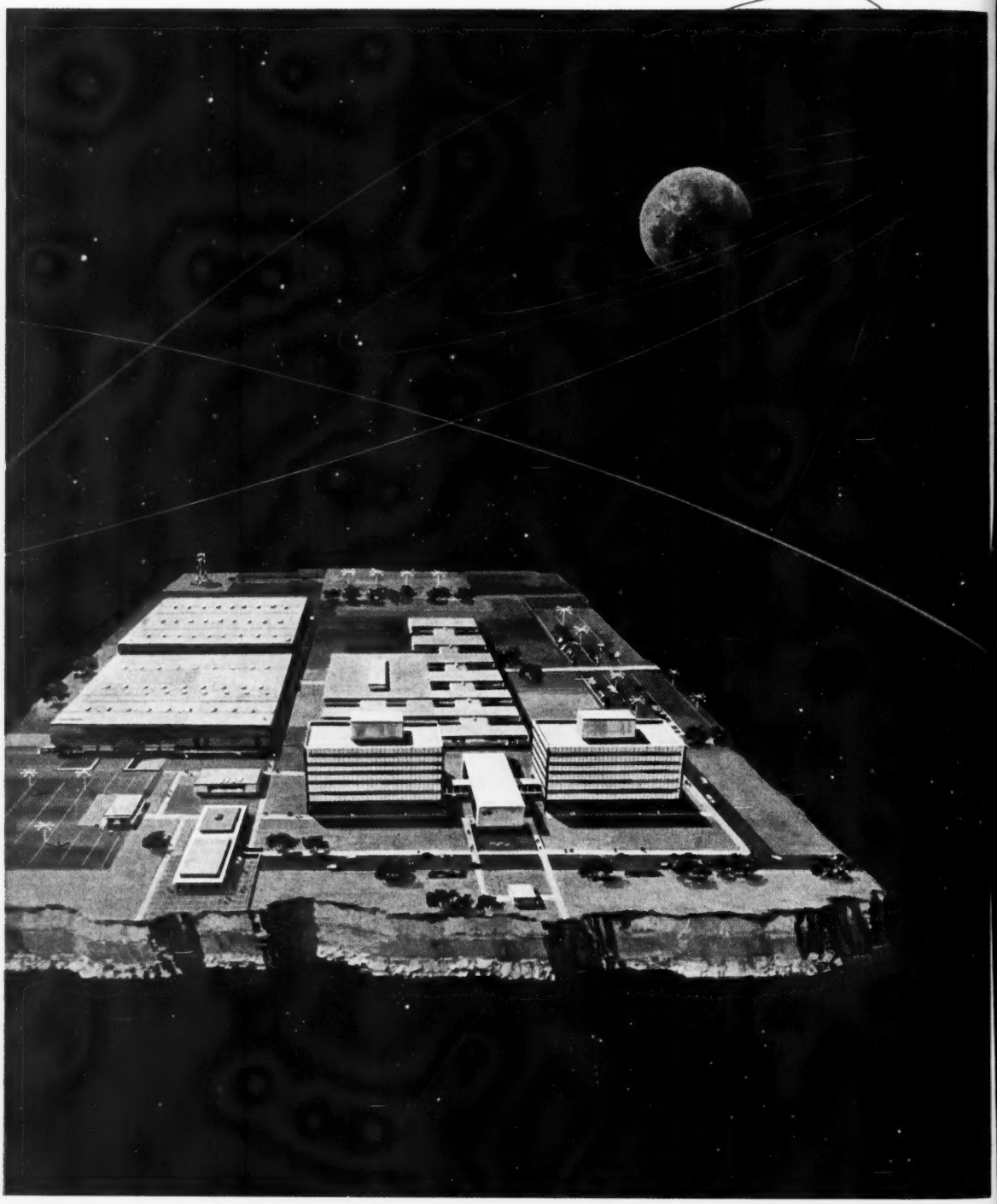
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